HAM TIPS

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Unusual Transmitter for the Novice Features the New RCA-6146

This Clean-Cut Unit Employs Conventional Circuits and a Number of Features Which Will Appeal to the Newly-Licensed, General-Class Operator

By

F. S. Barkalow,* W2BVS

General Description

THE transmitter shown in *Fig. 1* is an rf unit, complete with power supply, for cw operation on 80, 40, and 20 meters. As shown in the schematic diagram *Fig. 6,* the tube line-up starts with a crystal controlled pentode oscillator using a 6V6-GT. This stage is coupled to a 6146 beam-power final amplifier. This transmitter employs a common power supply for both the oscillator and the final, and features regulation of the oscillator plate voltage.

Another feature of general appeal is a tune-operate switch which increases the cathode resistance in the final amplifier during the initial tuning, thereby protecting the tube from accidental overloading. Also of interest is the use of a cathode-current (total tube current) milliammeter in the final; in the key-up position, this meter indicates grid drive directly. Keying is accomplished by means of a keying relay in the B+ lead of the 6146 final. For simplicity and low cost, plug-in coils and a crystal oscillator are employed. Frequency shifting is accomplished by means of crystal switching; however, a co-ax connector is provided for connection to an external VFO.

The power supply shown in *Figures 2, 4, and 6* delivers 600 volts dc, at currents up to 200 milliamperes. A conventional circuit is employed except for the inclusion of a pair of OD3's to regulate the plate voltage for the oscillator tube.

The two voltage-regulator tubes in series with variable resistor R_{13} are

**RCA Tube Dept., Harrison, N. J.*

CQ WN

Every serious-minded, dyed-in-the-wool Novice will profit greatly by reading W2BVS's article. It was written for the Novice by an ex-Novice after much consultation with the many old-timers at RCA.

The rig with the "commercial" appearance shown below is simply the result of applying a Novice's enthusiasm and ingenuity plus the old-timers' advice to a straightforward circuit. This transmitter was designed expressly for the Novice who is even now planning his future ham station. The design satisfies all of the present requirements of a good Novice transmitter, and already incorporates many of those inevitable changes and additions which usually result in the construction of a new rig.

Fig. 1. A well-designed transmitter for the Novice—a good start is always important!

connected from B+ to ground to provide the 300-volt regulated source of plate voltage for the oscillator tube. If an unregulated source is desired, a resistive voltage divider may be substituted for the regulator tubes and resistors R_{12} and R_{13} as shown in the schematic diagram. Note the addition of filter capacitor C_{12} at the junction of R_8 and R_{11}.

Resistor R_{12} discharges filter capacitors C_1 and C_2 when the power is turned off. The jumper in each of the regulator tubes (between pins 3 and 7) is wired in series with the primary of the power transformer so that the transmitter cannot be operated if these tubes are removed. Switch S_4 opens the ground connection to the center-tap of the high-voltage winding during stand-by periods. Indicator lamp PL_2 will glow when S_4 is closed.

Energizing voltage for the keying-relay coil (RL) is obtained from a 6.3-volt winding of the power transformer. This separate winding was used merely because it was available; the relay coil can be connected to the heater winding if a transformer having one heater winding is employed. The relay contacts break the 600-volt dc B+ line to the final amplifier tube.

Capacitor C_{13} and resistors R_9 and R_{10}, mounted at the relay contacts, comprise a key-click filter. A metal cover (not shown in *Fig. 2)* shields the relay and keeps the contacts dust-free. This filtering and shielding plus the use of the external ac line filter (shown in *Fig. 6)* are worthwhile precautions to prevent TVI.

Constructional Details

The rf unit and the power supply are built on separate 3 by 8 by 12-inch chassis. These chassis are attached to a standard 8¾-inch relay-rack panel. A single 3 by 12 by 17-inch chassis can be used instead of the two smaller chassis; however, the adjacent sides of these two chassis form a center partition which enables convenient mounting of the 6146 tank capacitor, shield, and

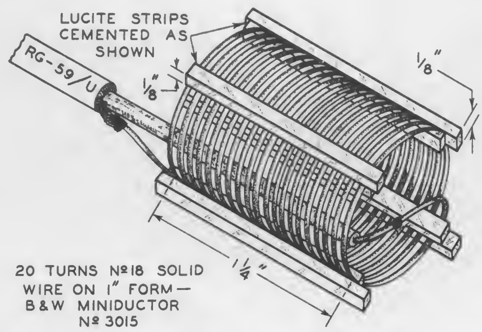


Fig. 3. Recommended method of connecting the coaxial transmission line to the antenna link. The additional Lucite strips keep the link from touching the tank coil.

bleeder resistors R_{12} and R_{13}. This arrangement also enables the builder to construct either one or both of the units, depending upon whether or not a suitable power supply is available.

From left to right on the front panel *(Fig. 1)* are shown the oscillator tank tuning control C_2, the crystal-selector switch S_1, the final amplifier plate tuning capacitor C_7, the plate-voltage switch S_4, power-on indicator lamp PL_1 (under which is located the key jack) and on the extreme right, the power-supply, on-off switch. The tune-operate switch S_2 is located above the final amplifier plate tuning control. To the right of S_2, and above the plate-voltage switch, is located the plate-voltage indicator lamp PL_2. The milliammeter located in the center of the front panel indicates cathode current of the final amplifier.

All of the major components are shown and identified in the photographs; the layout of parts was planned to permit simple wiring with short, direct leads. A common tie point should be used for all grounds in each stage. This practice, although not absolutely necessary for 80-meter operation, is recommended in the event this transmitter will be used for operation at higher frequencies.

The oscillator plate-tank capacitor and the rf amplifier plate-tank capacitor are spaced from the chassis and supported by ceramic insulators because the stator and rotor of each capacitor is above ground potential by the B+ voltage. Fibre shafts and flexible couplings are employed to keep these potentials from existing at the tuning knobs.

The rf amplifier plate-tank circuit is completely shielded from the grid circuit, both above and below the chassis, by two aluminum shields bent as shown in the photographs *Figures 2 and 5.* The base sleeve of the 6146

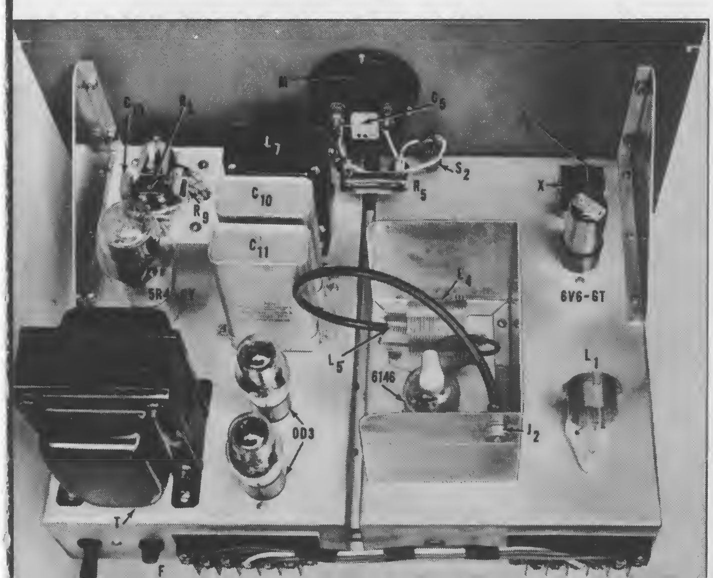
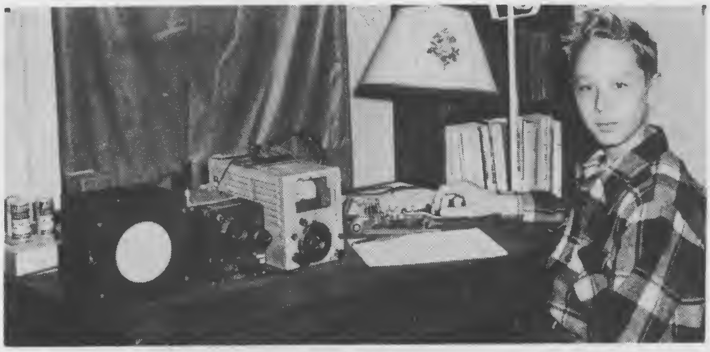


Fig. 2. This layout is a fine example of craftsmanship and simplicity. Although the use of the voltage regulator tubes in the power supply is highly recommended, they may be omitted if the beginner so desires; an alternative voltage divider is described in the text.

Second Novice License in 2nd District Held by Son of RCA's Frank F. Neuner, W2ZPD

A slice of the old ham! We're proud to introduce Frank J. Neuner, WN2IHS, who received his Novice license at the age of 14. He is a sophomore at Bloomfield (N. J.) High School. The transmitter at WN2IHS is a BC-457 (modified to crystal control) running 35 watts input on 3.735 Mc; the receiver is a BC-454. Frank is now studying for the General-Class examination. His dad is a Group Manager in the Product Administration Division, RCA Tube Dept., Harrison, N. J.



shields the input to the tube and isolates it from the output circuit. Pin 8, which is connected to the sleeve, must be grounded. Coupling the antenna to the final amplifier is accomplished by inserting a link L_5, into the cold (B+) end of tank coil L_4. This link is connected by means of a short piece of RG-59/U coaxial cable to the antenna connector J_2 mounted on the shield which surrounds the final amplifier tube and coil.

A piece of ¾-inch Celotex is placed between the relay and the chassis to deaden the sound of the relay armature. A metal cover for the relay should be provided for the reasons given under "General Description." Check the inside dimensions of the cover to make certain that there is sufficient spacing to clear all parts of the relay.

Adjustment and Tuning

Power Supply. Carefully check the power supply to make certain that it has been correctly wired and adjusted *before connecting it to the transmitter*. The only adjustment in the power supply will be the setting of the slider on resistor R_{13}. **(Always remove the line cord from the ac power source before any adjustments are made in the power supply.)** This adjustment can be made as follows: Insert a milliammeter between pin 2 of the lower regulator tube *(Fig. 6)* and ground, and adjust the slider for a current of 40 ma. (Caution should be observed when the adjustable slider on this resistor is moved. Resistors of this type are wound with very fine wire which can be easily damaged by the slider contact. *Before attempting to move the slider from one point to another along the bleeder, loosen the slider set-screw and rotate the slider so that the contact moves on the vitreous enamel coating and not on the wires.* After this adjustment is completed, reconnect pin 2 of the regulator tube to ground. Once the slider is set for this current of 40 ma, the oscillator plate voltage will be regulated at 300 v; this regulation will be maintained provided that the current drawn by the oscillator tube does not exceed 35 ma. Under normal operating conditions, a purple glow is visible in the regulator tubes; however, if the load current exceeds 35 ma, the glow will cease, thereby indicating a loss of regulation (this condition will occur if the 6V6-GT stops oscillating).

Oscillator. Insert the 80-meter coils and a crystal for the 80-meter Novice band. Before applying the power, make certain that the plate-voltage switch, S_4, is opened. Turn on the supply and allow sufficient time for the heaters to warm up. Then apply plate voltage to the oscillator by closing the plate-voltage switch. With the key up, oscillation should take place as capacitor C_2 is varied; oscillation will be evidenced by a small indication on the meter. The meter indicates grid current of the 6146 (approximately 3 ma) when the key is in the up position.* A ¼-watt neon lamp held near the oscillator plate coil will glow as a further indication of oscillation. If the oscillator plate coil is of the type specified and modified as noted in the parts list, oscillation will occur when C_2 is set at approximately half its maximum capacitance.

While capacitor C_2 is varied, note that the grid current of the 6146 rises gradually until a peak is reached and then it cuts off suddenly and oscillation ceases. The correct setting of C_2 is a point just before the peak is reached.

Final. When the tank circuit of an rf amplifier tube is tuned off resonance, the plate current increases. Because the off-resonance plate current of the 6146 will be quite excessive, care must be observed in order to prevent damage to the tube and/or the meter.

To prevent damage to the 6146 and the meter while locating the resonant setting of C_8, a tune-operate switch, S_2, is incorporated in the circuit. In the "TUNING" position of S_2, a fairly high resistance (R_4) is placed in series with the cathode resistor of the 6146 to limit the plate current to a safe value. With S_2 in the "TUNING" position and with the antenna disconnected from link L_5, the tank capacitor should be tuned for resonance.

**The meter indicates 6146 cathode current (total tube current) when the key is pressed.*

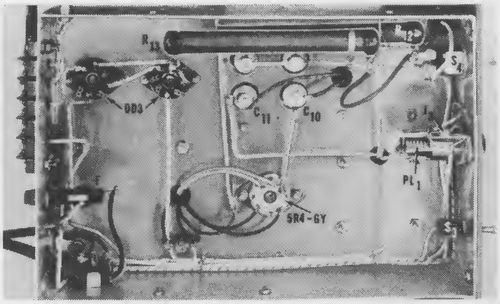


Fig. 4. An example of neat wiring. Note that R_{13} is mounted above R_{12} to permit easy access to the adjustable slider.

After the resonant setting has been found, throw S_2 to the "SEND" position to short out resistor R_4; connect the antenna to the loosely coupled variable link L_5. The tank capacitor C_7 should be readjusted for resonance. Check the 6146 plate current for this amount of antenna loading. The loading can be increased by moving the link further into the tank coil and retuning for resonance. **(Do not attempt to adjust the link when the power is on.)** With 600 volts on the plate of the 6146, the loading can be increased up to a maximum plate current of 150 ma* for an input of 90 watts (for General-Class operation).

Since the meter indicates cathode current, it is necessary to subtract the control- and screen-grid currents from the meter reading to obtain the plate-current value for a determination of the power input to the 6146 (At the maximum input of 90 watts, the screen current will be approximately 15 ma with a recommended grid-No. 1 current of 3 ma.).

Operation on 40 meters is possible with either a 40- or 80-meter crystal and a 40-meter oscillator tank coil. If an 80-meter crystal is used, the 6V6-GT functions as an oscillator-doubler. Similarly, 20-meter excitation for the 6146 is obtained by using a 40-meter crystal and tuning the plate circuit of the "oscillator" to 20 meters. The 6146 operates straight through on 80, 40, and 20.

It is desirable to have some means for checking the oscillator and final tank circuits to make certain that they are tuned to the desired bands rather than to harmonics, particularly if a substitution of components has been made for those specified in the parts list. Either an absorption-type wavemeter or a grid-dip meter may be used for this purpose. It is well for the Novice to remember that crystal control does not insure the operator against outside-the-band operation. After making certain that C_2-L_1 and C_8-L_4 are tuned to the desired bands, a wavemeter or a receiver should be used to check the output of the transmitter to determine whether harmonics are present.

TVI

This transmitter was operated on 80 meters with a half-wave doublet antenna fed with RG-59/U coaxial cable.

Operation of the transmitter without the cabinet resulted in serious TVI (on all channels) on a set of 1947 vintage which was located 300 feet from the transmitter. TVI was also encountered in the writer's TV set (on all channels) which was located approximately 30 feet from the transmitter; the spacing between the TV antenna and the transmitting antenna is approximately 30 feet.

Placing the transmitter in an unaltered metal cabinet eliminated both of these cases of TVI completely. The closest neighbor (100 ft away) reports that he hasn't any TVI. As a check, the writer's TV set was operated at a distance of four feet from the transmitter (with an indoor folded dipole); it was impossible to find any trace of TVI. Additional TVI precautions (such as the use of lead filters, a low-pass filter, cabinet alterations, etc.) may be necessary when this transmitter is operated on 40 or 20 meters. The Summer, 1951 issue of HAM TIPS contains an excellent article (including many references) on the elimination of TVI.

Key clicks which were heard in both an ac/dc receiver and a phono player were eliminated by building a filter (see *Fig. 6)* and inserting it between the power-supply line cord and the ac outlet.

**ICAS, class C telegraphy.*

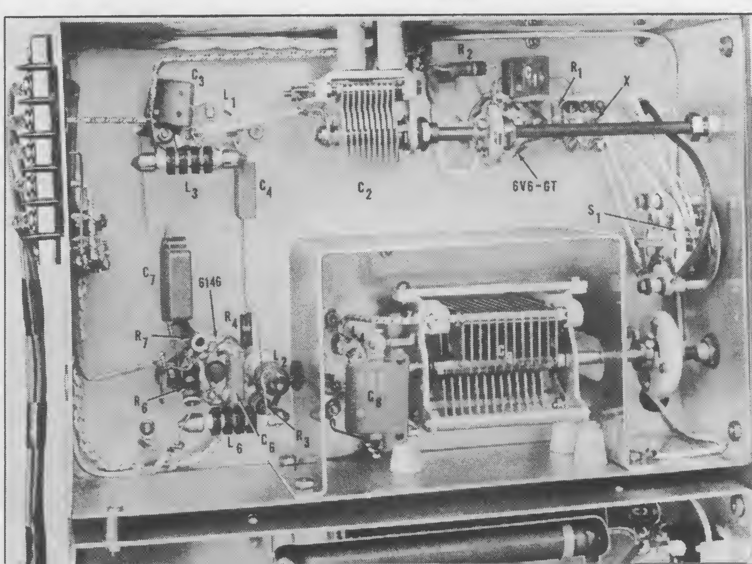


Fig. 5. A close-up of the rf chassis. Note that coupling capacitor C_4 is mounted with its edge toward the chassis to minimize stray capacitance, thereby preventing a waste of driving power. The twisted leads running along the bends of the chassis supply heater voltage to the tubes.

On-the-Air Performance

During a one-month period of operation on 80 meters, 30 states were worked as well as Canada. Very fb reports were received on the quality of the note. The results were most gratifying and proved the RCA-6146 to be a tube with a bright future.

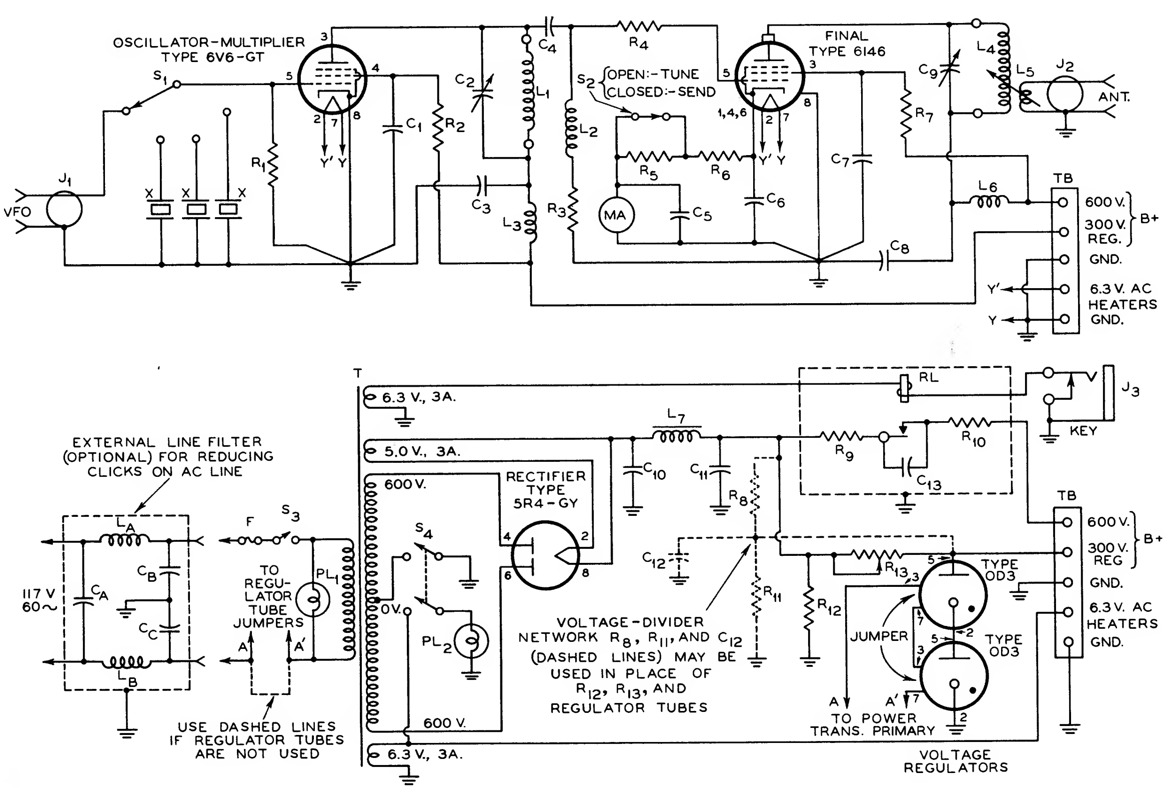


Fig. 6. Schematic diagram of the transmitter and power supply.

Transmitter

C_1, C_3, C_5, C_6	0.005 μf, mica, 500 v.
C_2	100 $\mu\mu f$, variable (National TMS100).
C_4	50 $\mu\mu f$, mica, 500 v.
C_7, C_8	0.005 μf, mica, 1,500 v.
C_9	150 $\mu\mu f$, variable (National TMK150).
J_1, J_2	Amphenol 75PC1M.
L_1	B & W MEL, 16 turns removed (80 meters)—see text.
L_2, L_3, L_6	2.5 mh (National R100).
L_4	B & W 80 JEL, 8 turns removed. B & W 40 JEL B & W 20 JEL
L_5	20 turns B & W Miniductor 3015.
M	0-200 ma type 301.
R_1, R_2	50,000 ohms, 1 watt.
R_3	47,000 ohms, 2 watts.
R_4	50 ohms, 1 watt.
R_5	750 ohms, 25 watts (Ohmite 0203).
R_6	50 ohms, 2 watts.
R_7	25,000 ohms, 10 watts (Ohmite Brown Devil).
S_1	Mallory "Hamband" switch.
S_2	SPST, toggle, 125 v, 3 amp.
TB	Jones 5-142Y.
X	Crystal, 3.5 or 7 Mc (see text).

Power Supply

C_{10}, C_{11}	4 μf, oil-filled, 1000 wv (Cornell-Dubilier TJU 10040J).
C_{12}*	8 μf, electrolytic, 600 wv.
C_{13}	0.002 μf, mica 1,500 v.
F	3AG 3 amp (for Littlefuse 342001 holder).
J_3	Closed-circuit type (Mallory A2).
L_7	6 h, 200 ma (Thordarson 20C55).
PL_1	125 v, 6 watts.
PL_2	6.3 v.
R_8*	7,500 ohms, 50 watts (Ohmite 0579).
R_9, R_{10}	50 ohms, 1 watt.
R_{11}*	30,000 ohms, 50 watts (Ohmite 0586).
R_{12}	25,000 ohms, 75 watts (Ohmite 0788).
R_{13}	10,000 ohms, adjustable, 75 watts (Ohmite 0783).
RL	6.3 v (Guardian K320).
S_3	SPST, toggle, 125 v, 3.5 amp.
S_4	DPST, toggle, 125 v, 3.5 amp.
T	600-0-600 v, 200 ma; 5 v, 3 amp; 6.3 v, 3 amp; 6.3 v, 3 amp (Stancor type PC8414).
TB	Jones 5-142Y

*Components for alternative voltage divider.

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Vol. 12, No. 3 November, 1952

An All-Band Antenna and Coupler

By

J. H. Owens,*W2FTW

DO you want to work 75 or 80, 40, 20, and 10 meters with a single sky-wire? Is your space limited, and cost a factor? If so, here is a way to do it—with actual performance advantages over simple dipoles for each band.

The general idea is to take a 75/80-meter dipole and fold it so that desirable standing-wave voltage and current relationships are maintained on the higher-frequency, harmonically-related bands.

Fig. 1 shows the configuration and dimensions of the antenna. It is simply a 75/80-meter dipole with the ends folded back and over the center portion. It must radiate because it is resonant and unshielded. Since it radiates the energy that is fed to it, the only other major consideration is directivity. In this respect, it is less directional than a straight-line 75/80-meter dipole, and the angle of radiation is somewhat higher. This latter characteristic is desirable if you want to join the Rag Chewers on 75 and make regular contacts with stations inside a two- or three-hundred mile radius.

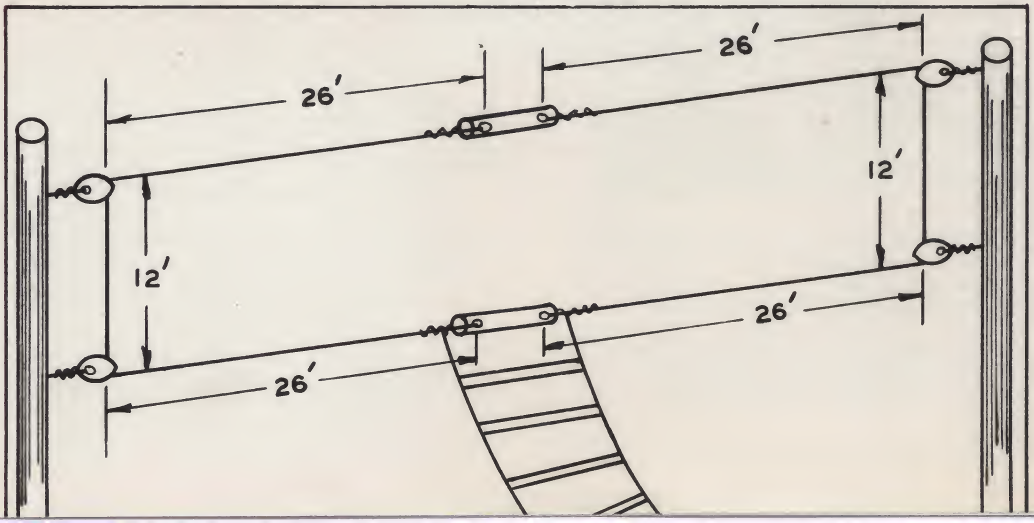
Fig. 2a shows maximum voltage points when the antenna is used on 40 meters. The antenna consists of two half-wave dipoles, partially folded, vertically polarized, and 180 degrees out of phase. The angle of radiation is somewhat lower than that of a dipole of equivalent height, and the directivity pattern is slightly end-fire.

Voltage points for 20-meter operation are shown in *Fig. 2b*. Here, the antenna approximates a beam because it provides two half-waves in phase on one side, which are in phase with the two in-phase half-waves on the other side. Best DX is obtained in the broadside direction in which the angle of radiation is low, but there are some minor lobes which provide satisfactory operation in all directions during periods of short skip.

Similarly, *Fig. 2c.* shows voltage points for ten meters. This arrangement provides two full-waves in phase on one side, but 180 degrees out of phase with the two in-phase full-waves on the other side. The field pattern is quite complex, and for all practical purposes may be considered omnidirectional. The pattern con-

* *RCA Tube Dept., Harrison, N. J.*

Fig. 1. Layout and dimensions of the all-band antenna.



tains major lobes each having a low angle of radiation—a highly desirable feature for 10-meter DX.

Antenna Coupler

Like most all-band antennas, this one should be fed with tuned open-wire feeders employing four- or six-inch spreaders. An antenna coupler is employed to provide an impedance transformation, a means for tuning the antenna and feeders to resonance, and attenuation of harmonics. Any of the well-known antenna couplers will perform these functions conveniently and economically.

The coupler shown in *Fig. 3* is electrically the well-known, Pi-section filter with link coupling. It consists of two variable capacitors and a swinging-link, push-pull plate tank coil —the one for the next lower frequency band than the band to which the final amplifier is tuned. For instance, if the transmitter is being operated on 20 meters, the 40-meter coil would be used in the coupler.

Capacitors C_1 and C_2 can be of the split-stator type if the capacitance per section is double the values shown. Single-stator capacitors have been used with excellent results. The voltage rating of C_1 should be equal to that of the tank capacitor in the final amplifier, but C_2 need have a voltage rating of only half as much. Depending upon the length of the feeders, optimum loading may be obtained by connecting them across C_1 or C_2.

Tuning

In operation, the coupler is first tuned to resonance as indicated by an increase in the plate current of the final amplifier. The ratio of the capacitance of C_1 to C_2 is then varied to provide maximum loading of the final amplifier, and the swinging links are adjusted for desired plate current. The tuning procedure is the same for all bands.

Good results were obtained on all bands from 80 to 10 meters with an antenna less than 60 feet long and with its upper radiator only 20 feet above ground.

Do You Know of Any Would-Be Hams?

"You Can Be There" is an interesting pamphlet published by the American Radio Relay League to promote interest in the Novice Class, amateur-radio license. This booklet describes the romance and adventure to be derived from personal two-way, amateur-radio communication with stations throughout the world.

Copies of the pamphlet may be obtained by writing to the ARRL, West Hartford 7, Conn.

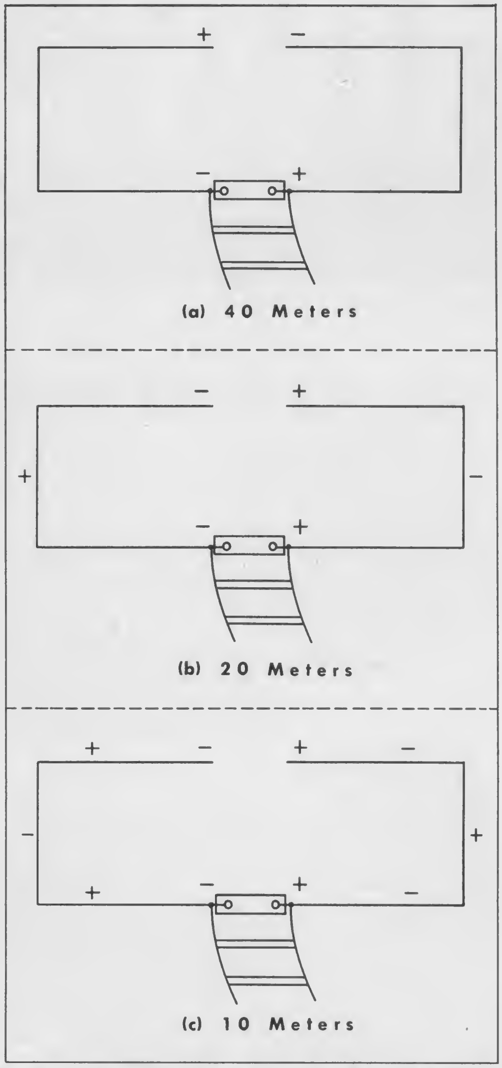


Fig. 2. Maximum voltage points on the antenna for 40-, 20-, and 10-meter operation.

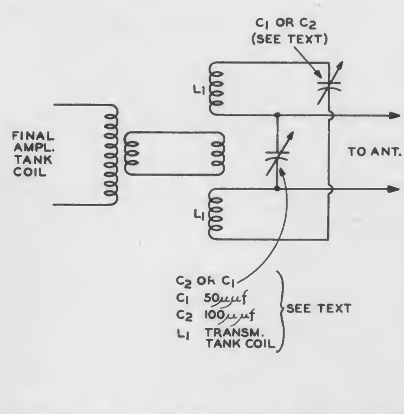


Fig. 3. Circuit of the antenna coupler used with the all-band antenna.

A New Superhet S-Meter Circuit

Combining the Second-Detector, AVC, Automatic Noise Limiter, First-Audio Stage, with a Bridge-Type Signal-Strength Meter

By
J. H. Owens, W2FTW

THIS article is another proof of the adage, "Necessity is the mother of invention." The equipment with which the author had to cope was a prewar "home-brew" receiver which performed better than many commercially-built receivers, but lacked such refinements as a signal-strength meter and an effective noise limiter. Although ways and means of adding these refinements are revealed in various publications, a new method had to be devised because the lack of chassis space prohibited the use of additional tubes.

It was indeed a difficult problem, but its eventual solution was accomplished by the use of well-known circuitry, two tubes, a 0-1 milliammeter, and relatively few components in a novel arrangement. The novelty lies in a unique circuit which takes full advantage of the many possible circuit arrangements for the multi-section tubes that were selected to replace those in the original complement. The circuit is shown in *Fig. 1.*

Second Detector and AVC Circuit

The second detector is the usual half-wave rectifier (one half of a 6H6) connected to the secondary of the last if transformer. The load network consists of R_2 and R_3, bypassed at the intermediate frequency by capacitors C_1 and C_2. AVC bias voltage is taken from the diode-load network and fed to the avc filter through R_1. If the receiver uses both sharp-cutoff and remote-cutoff tubes in the rf or if amplifiers, it may be desirable to supply two or more levels of avc bias.

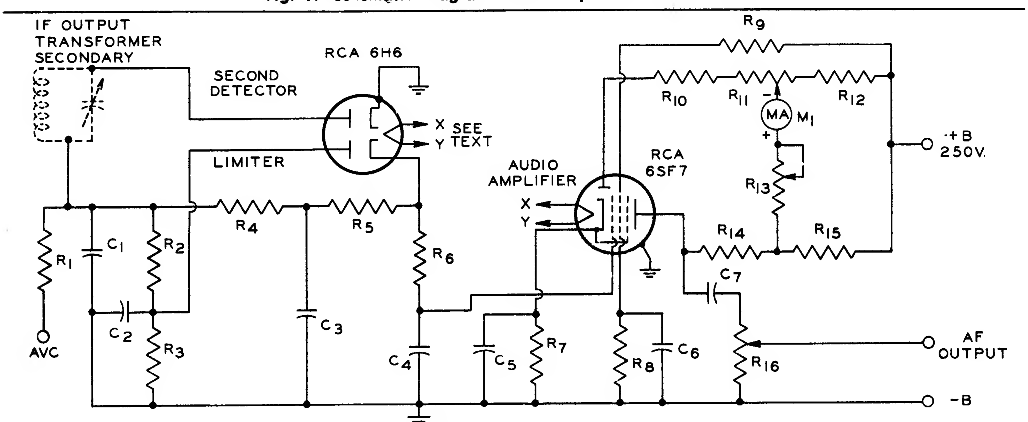
Tubes having a remote-cutoff characteristic should be biased through R_1 from the top of the network; tubes having a sharp-cutoff characteristic should be fed through another 2.2-megohm resistor from the center or other point on the network obtained by substituting two series-connected resistors in place of either R_2 or R_3. The rf amplifier tubes should be fed with only enough avc bias to prevent strong signals from overloading the if amplifier, because high gain in the rf stage is conducive to the best signal-to-noise ratio.

Automatic Noise Limiter

The popular "series-valve" circuit was selected for the automatic noise limiter because of its superior effectiveness, and also because it generates less of the raspy type of audio distortion so common to the "shunt-valve" circuits. The network is composed of the other diode section of the 6H6 together with R_4, R_5, C_3 and the diode-load network. A full explanation of the operation of this circuit can be found in the ARRL Handbook.

The only disadvantage of the series-valve limiter is a possibility of hum pickup. Capacitive coupling and ohmic leakage between the diode heater and its cathode can produce hum because the cathode is in a very-high-impedance,

Fig. 1. Schematic diagram of the superhet S-meter circuit.



Parts List

C_1, C_2 500 $\mu\mu$f, mica.
C_3 0.05 μf, paper, 400 v.
C_4 100 $\mu\mu$f, mica.
C_5 10 μf, electrolytic, 10 v.
C_6 0.05 μf, paper, 400 v.
C_7 0.05 μf, paper, 600 v.
M_1 0-1 milliammeter.

R_1 2.2 megohms.
R_2, R_3 270,000 ohms (See text).
R_4, R_5 1 megohm.
R_6 100,000 ohms.
R_7 150 ohms.
R_8 86,000 ohms (See text).

R_9 100,000 or 180,000 ohms (See text).
R_{10} 68,000 ohms.
R_{11}, R_{13} 500 ohms, w. w. potentiometer.
R_{12} 330 ohms.
R_{14} 47,000 ohms.
R_{15} 560 ohms.
R_{16} 1 megohm, potentiometer, audio taper.

NOTE
(All resistors ½ watt)

MEET THE AUTHOR
J. H. Owens, W2FTW

W2FTW since 1946, ex-W3ASZ since 1932.

Home QTH: Merchantville, N. J.

Active on: 75- and 10-meter phone.

Rigs: 100 watts to an 829-B on 75, and 15 watts to a 2E26 on 10.

XYL: Marty.

Harmonics: James, Constance, and Susan.

Started career as a commercial radio operator. Joined RCA Photophone, Inc. in 1930. Transferred to Commercial Sound Div. of RCA during World War II. Joined Renewal Sales Section of the Tube Dept. in 1946. First post-war editor of HAM TIPS. Now Manager of Test and Measuring Equipment Sales.

---

unbypassed circuit. Hum pickup can be avoided by employing a power transformer having a center-tapped and grounded heater winding. Another alternative is the use of a germanium rectifier; however, the conduction of this device in the reverse direction does not cut off completely—a characteristic which would lower its efficiency as a limiter.

In the author's receiver, one side of the heater-transformer winding is grounded; therefore, an RCA 6H6 was chosen for the limiter rectifier because its internal design is such that grounding either side of the heater transformer winding is just as effective as grounding a center-tap in keeping hum at a minimum. Because there are two 3.15-volt, series-connected heaters in the 6H6, the ac voltage difference between heater and cathode is reduced by 50 per cent as compared to that of many 6.3-volt, heater-cathode tubes. Furthermore, the RCA 6H6 employs double-helically wound heaters which make the tube inherently less susceptible to hum than a tube having a folded heater. The only precaution to be observed in grounding one side of the heater-transformer winding is the requirement that the limiter circuit employ the diode having the grounded heater. For example, if heater pin 2 is grounded, the diode connected to pins 3 and 4 should be used as the limiter; if heater pin 7 is grounded, then the diode connected to pins 5 and 8 should be used. The other diode section is then used as the detector. If these precautions are followed, no perceptible hum should be encountered.

Audio Amplifier

The audio amplifier is "diode-biased" for two reasons. First, this system keeps the ac/dc impedance ratio of the diode load near unity, a requisite for handling, with low distortion, signals having a high percentage of modulation. Secondly, this system provides a source of B+ voltage which varies in proportion to the input-signal level—a requisite for the S-meter circuit. Because the tube grid has to handle the avc voltage plus audio modulation, a low-mu or remote-cutoff characteristic is also required; otherwise, strong signals would cut off the plate current completely. The 6SF7 was chosen for this stage because of its large-signal-handling ability, plus the availability of a diode section which is used in the S-meter circuit. Note that the control-grid is fed through an RC network (R_6-C_4) which de-emphasizes frequencies above approximately 5 Kc.

The 6SF7 is shown in the circuit with its screen-grid voltage taken from a bleeder network. This connection should be used if the receiver if amplifier uses only semi-remote-cutoff tubes (such as the 6SG7, 6BA6, or 6BJ6) and if the avc bias voltage is taken from the top of the diode-load network. If remote-cutoff tubes are used (such as the 6SK7, 6BD6, or 6SS7) in the if amplifier, the circuit should be modified so the 6SF7 acts like a triode insofar as avc signal bias is concerned.

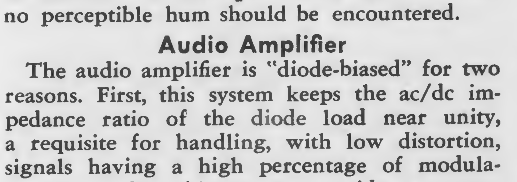


Fig. 2. Scale for the S-meter. The lower half is divided into nine equal divisions, and the upper half into four equal divisions (representing 10-db steps over S-9).

This modification can be made by removing bleeder resistor R_8 and changing the value of dropping resistor R_9 to 180,000 ohms. The screen-grid voltage will then swing up and down with changes in signal level, and the cutoff characteristic of the tube will be greatly extended. With this circuit arrangement, the 6SF7 functions as a triode insofar as avc bias is concerned, but retains the high gain of a pentode insofar as audio is concerned. In both cases, a small amount of cathode-resistor bias is used to minimize the effects of contact potential, a variable factor which might upset normal operation of the circuit.

The output-circuit constants, coupling capacitor C_7 and volume control R_{16}, were chosen especially to feed the grid of a power-output tube. A pair of crystal phones will work well if it is connected between the arm of the volume control and ground. A modification can be made for efficient operation of magnetic-type phones by changing the volume control to a 100,000-ohm unit and adding a matching transformer with its primary connected between the volume-control arm and ground, and the phones connected across its secondary.

S-Meter Circuit

In the S-meter circuit, a novel adaptation of an electronic-bridge circuit is employed to obtain a difference in voltage between two

points in a divider network. The 6SF7 plate and diode function as two arms of the bridge circuit so that the voltages across the bridge terminals depend upon the flow of electrons in a single tube. This arrangement prevents violent deflection of the meter needle when the receiver is first turned on because current starts to flow in each section quite uniformly as the cathode warms up.

This circuit has the desirable feature of up-scale meter deflection for an increase in strength of the received signal. Zero-adjustment is obtained by means of potentiometer R_{11}; this control locates a voltage point on the diode arm which is equal to the voltage at the junction of R_{14} and R_{15} (in the plate-circuit arm) during the absence of signal. When a station is tuned in, the detector develops a negative bias which is applied to the grid of the 6SF7 and, in turn, reduces the dc plate current without affecting the diode current. This reduction in plate current produces an increase in voltage at the positive meter terminal; the voltage at the negative meter terminal remains fairly constant. Thus, the meter is deflected by the current that flows as a result of the voltage difference across its terminals.

Depending upon the gain and the cutoff characteristics of the rf and if tubes used in the receiver, some minor adjustment of the bridge-circuit constants may be necessary in addition to the 6SF7 screen-grid circuit changes previously mentioned. High receiver gain and remote-cutoff tubes will act together to develop rather high avc bias which in turn causes wide-scale deflection with fairly weak signals. Conversely, low receiver gain and sharp-cutoff tubes can develop only a small amount of avc bias even when strong signals are received. Potentiometer R_{13} is a fine-adjustment control for setting the meter to S-9 for a signal that is just strong enough to quiet all of the receiver background noise.

No difficulty should be experienced if the screen-grid circuit of the 6SF7 is set properly so that its cutoff characteristic matches the cutoff characteristics of the tubes in the if amplifier, and if the proper avc bias on the diode-load net-work is selected.

Calibration of the S-meter scale is somewhat academic at best, inasmuch as the S-meter readings for most receivers are a function of receiver sensitivity (which varies with frequency) as well as with the level of the signal on the antenna-input terminals. In this circuit, meter deflection is quite logarithmic, thereby allowing uniform spacing of the scale divisions to indicate power levels in a db ratio. A satisfactory scale is shown in *Fig. 2.*

Adjustment

If a 22.5-volt "B" battery (such as the RCA VS102) is available, it will be found very useful in the adjustment of R_{13}. Connect a 50,000-ohm potentiometer across the battery terminals; then connect the positive terminal to ground. Next, connect the potentiometer arm to R_1 at the point marked "AVC." With the receiver rf gain control set at maximum, rotate the arm to the point where the receiver background noise disappears. The voltage on the arm of the potentiometer is now the same as the avc voltage that would be developed by an S-9 signal. Disconnect the arm of the battery potentiometer from R_1; connect it directly to the grid of the 6SF7, and adjust R_{13} so that the meter indicates S-9. This method is more convenient than listening for a signal of exactly S-9 strength.

Conclusion

This circuit was developed for a home-built communications receiver and is not intended as a suggested modification for commercially-built receivers. It is offered to the radio amateur who would like to further refine his own home-brew superhet.

It performs excellently, and the audio quality is good enough so that means for switching the limiter diode in and out of the circuit are not required.

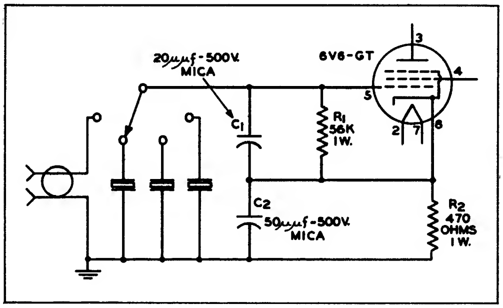
OMISSIONS
(Novice-Transmitter Article)

As originally conceived by W2BVS, the Novice transmitter described in the July 1952 issue of HAM TIPS was designed for operation on 80 meters.

The design was later changed to appeal to the General-Class operator by using plug-in coils for 80, 40, and 20 meters, and by modifying the basic crystal-oscillator circuit to the grid-plate type.

We neglected to inform our drafting department of the circuit changes; consequently, the schematic diagram on page 5 of the July issue contains the original oscillator circuit.

The changes shown in the following schematic diagram are necessary to obtain harmonic output from the oscillator.



Additions to Original Parts List

L_1 B & W 40M "Baby," 8 turns removed.
B & W 20M "Baby," 6 turns removed.

Optional Line Filter

C_A, C_B, C_C 0.01, μf, 600 v.
L_A, L_B 35 turns No. 12 solid enameled wire on a ½-in. diam. fibre (or wooden dowel) form. Wound to a length of 2½ inches.

RCA Receiving Tubes useful in Amateur Transmitters

	RCA Type Number	RF Service: VFO	RF Service: Xtal OSC	RF Service: Frequency Multiplier	RF Service: Buffer	RF Service: Final	AF Service: Voltage Amplifier	AF Service: Driver	AF Service: Modulator
Octal-Base Types	6AG7	6AG7	6AG7	6AG7	6AG7	6AG7			
	6F6		6F6	6F6	6F6	6F6			6F6
	6J5						6J5	6J5	
	6J7						6J7		
	6L6		6L6	6L6	6L6	6L6		*6L6	6L6
	6N7			6N7					6N7
	6SJ7						6SJ7		
	6SL7-GT							6SL7-GT	
	6SN7-GT						6SN7-GT	6SN7-GT	
	6V6-GT		6V6-GT	6V6-GT	6V6-GT	6V6-GT			6V6-GT
Miniature Types	†5879						5879		
	6AF4	6AF4							
	6AK6	6AK6	6AK6	6AK6	6AK6				
	6AQ5								6AQ5
	6C4	6C4	6C4	6C4			6C4	6C4	
	6J6	6J6	6J6	6J6	6J6	6J6			
	12AX7						12AX7		

*Triode Connected

†Special Type

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Joseph Pastor, Jr., *Editor* W2KCN

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HAM TIPS

A PUBLICATION OF THE TUBE DEPARTMENT · RCA · HARRISON, N. J.

Volume 13, No. 1 January - March, 1953

GEORGE M. ROSE, K2AH, AND HIS HISTORY-MAKING, 146-MC TRANSISTOR TRANSMITTER (See page 3 for story.)

Construction of Inductors for TVI Filters

By
Mack Seybold,* W2RYI

Many of the published articles on the construction of low-pass filters include complete instructions for winding the inductors required for the filter sections. If the author's work is duplicated, and if the directions for winding the coils are followed implicitly, no difficulty will be encountered in building and adjusting the filter. However, the average amateur may experience considerable difficulty if he chooses to modify the original design to suit his particular needs; he may be handicapped by lack of references on the construction of coils which will fulfill given requirements of inductance and Q.

*Tube Dept., Radio Corp. of America, Harrison, N. J.

This article supplies easy-to-follow instructions for winding inductors to given inductance specifications, and describes methods for checking inductance with an accuracy adequate to meet the requirements for practical TVI filters.

Construction

A single-turn flat loop as shown in *Fig. 1* is satisfactory for an inductance of 0.03 to 0.1 μh. For inductances greater than 0.1 μh, the inductor may be wound as a conventional coil having several turns, as shown in *Fig. 2*, in order to conserve space and to maintain a reasonable Q.

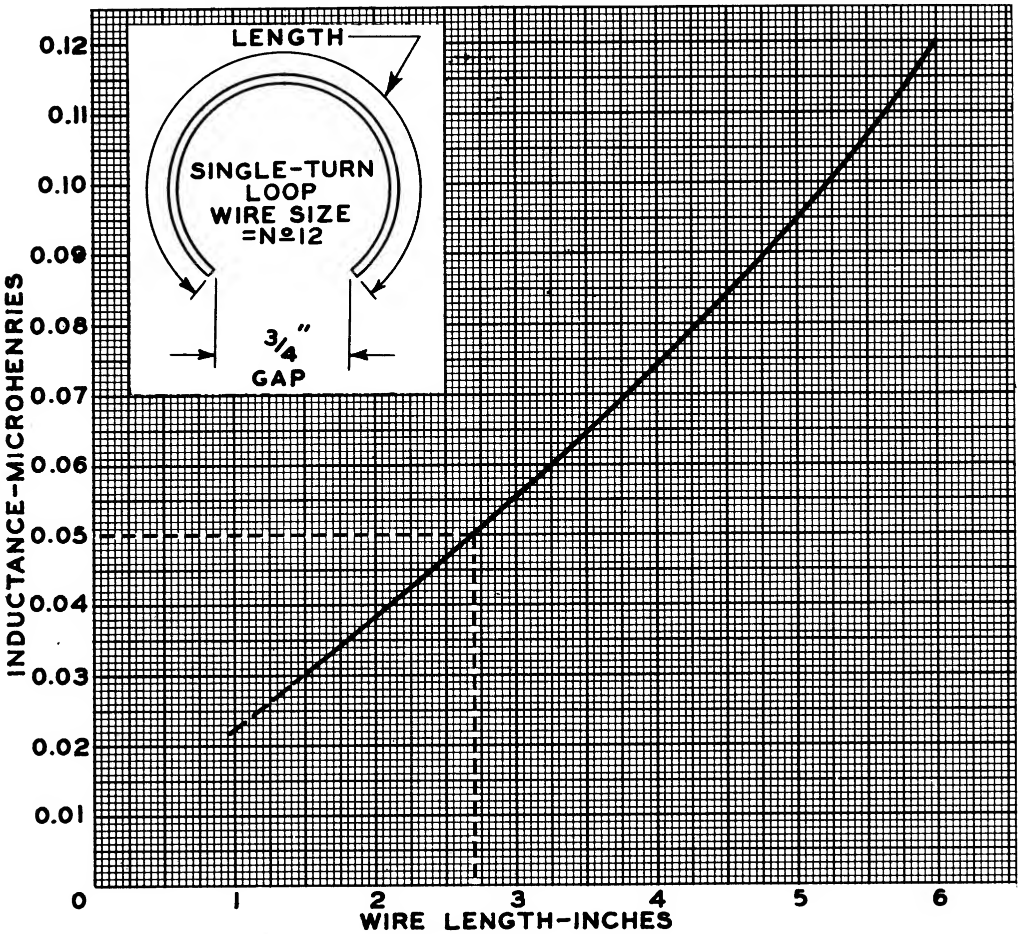


Fig. 1. Curve for determining the dimensions of a single-turn, flat loop (for inductance values of 0.03 to 0.1 μh).

COVER PHOTO

History in the making! George M. Rose (K2AH), Manager of the RCA Tube Department's Advanced Development Group, is shown keying a 146-Mc transistor transmitter. We believe this to be the first use of a transistor in two-way radio communication.

This preview of "things to come" was made possible by the use of a developmental-type transistor now being studied in the RCA Tube Department's laboratories. With this small experimental battery-operated crystal oscillator, K2AH of Mountain Lakes, N. J. contacted W2KNI, Mountainside, N. J. (16 mi. away), W2DPB, E. Orange, N. J. (16 mi. away), and W2UK, New Brunswick, N. J. (25 mi. away)!

According to George, power input to this tiny rig was 30 milliwatts (10 v at 3 ma). This transmitter, employing a point-contact transistor and a 16-Mc crystal operating on its 9th overtone, is powered by a 22½-volt, hearing-aid battery. The transmitting antenna at K2AH is a 12-element beam and the receiving antennas at W2KNI, W2DPB, and W2UK contain 10, 6, and 40 elements respectively.

RCA transistors are still in the developmental stages but when they become commercially available, you will be so informed by an announcement in HAM TIPS.

Example 1. The dimensions of a 0.05-μh inductor can be found from *Fig. 1*. The dashed lines indicate how the wire length (2.7 inches) can be read from the curve opposite the inductance of 0.05 μh. This length of No. 12 wire, when formed into a single-turn flat loop having a ¾-inch gap between the ends of the wire as shown in *Fig. 1*, will have an inductance of 0.05 μh.

Example 2. If a 0.25-μh inductor is required, the number of turns can be determined from *Fig. 2* as shown by the dashed lines. If 3.4 turns of No. 12 wire are wound with a pitch of eight turns per inch and the diameter of

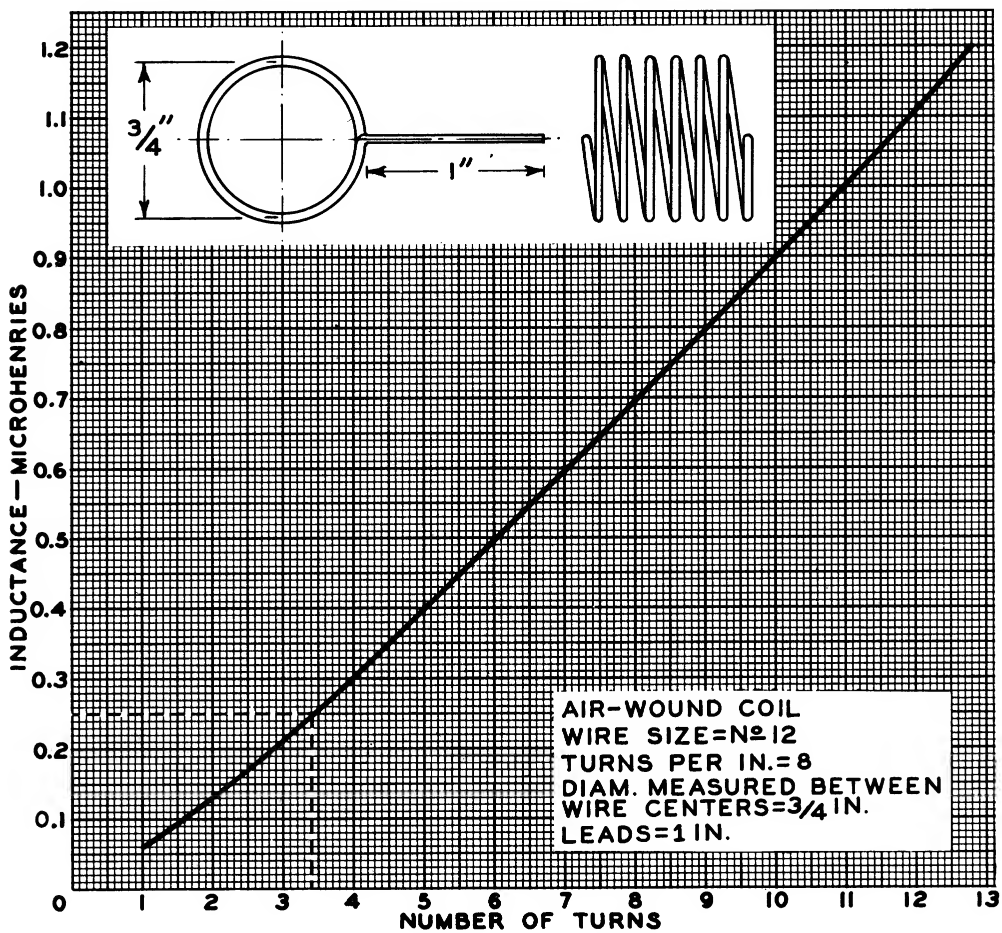


Fig. 2. Curve for determining the number of turns for inductance values greater than 0.1 μh.

the coil is ¾ inch (measured from the center of the wire as shown in *Fig. 2*), the coil will have an inductance of approximately 0.25 μh (including the inductance of the one-inch leads).

Coils wound in accordance with *Figures 1* and *2* are sufficiently accurate for most TVI applications; they may be soldered into a low-pass filter without further adjustment.

If desired, the coil may be wound to other dimensions. The nomograph shown in *Fig. 4* facilitates the selection of suitable values of inductance and capacitance for a circuit resonant at a given frequency. For example, the inductance necessary for resonance at 67.25 Mc with a 20-$\mu\mu$f capacitor can be determined by placing a straight-edge on the nomograph so that it connects the 67.25-Mc point on the frequency scale and the 20-$\mu\mu$f point on the capacitance scale. The intersection of the straight-edge with the inductance scale determines the required inductance value. The inductance, capacitance, and frequency ranges covered in this nomograph are applicable to most low-pass, TVI filter designs.

Measurements

The inductance of the coil may be measured with a Q-meter, or it may be checked in a resonant circuit with a grid-dip meter as shown in *Fig. 3*.

To facilitate measurement of inductance in a resonant circuit with a grid-dip meter, a calibrated variable capacitor should be included in the resonant circuit. Since such a capacitor cannot be found in the average ham shack, a reasonably accurate capacitance standard can be made from a set of six silver-mica capacitors—one each of 5, 10, 20, 40, 70, and 100 $\mu\mu$f (five per cent tolerance). Combinations of these six capacitors will provide a capacitance range of 5 to 150 $\mu\mu$f in 5 $\mu\mu$f steps. Errors can be kept to a minimum by clipping the capacitor leads short and by soldering short connections to the coil being tested. Lumping of capacitance-tolerance error can be minimized by using a single capacitor whenever feasible rather than a combination of capacitors; the use of a single capacitor is practical when the frequency of the signal source can be varied.

The XYL's TV receiver can be used to calibrate the grid-dip oscillator. One or two wide, black, vertical bars will be visible on the kinescope when the grid-dip oscillator frequency is approximately the same as the picture-carrier frequency. When the oscillator frequency approaches the sound-carrier frequency, a T-6 c.w. signal will emanate from the speaker. The distance between the TV antenna transmission line and the grid-dip meter may be five feet or more during this calibration. TV sound– and picture-carrier frequencies for several channels are indicated on the nomograph, *Fig. 4,* for convenient reference when a TV receiver is used for calibrating the grid-dip oscillator.

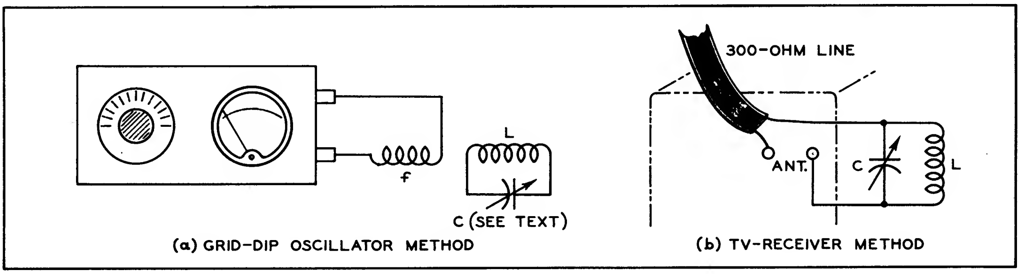
The TV receiver can also be used, alone, as a resonance indicator when a grid-dip meter is not available.* When this method is employed, the parallel resonant circuit containing a known capacitance and an unknown inductance is connected between one side of the 300-ohm transmission line and the TV receiver antenna terminal as shown in *Fig. 3b.* When the inductor and the capacitor are resonant at a picture-carrier frequency, the picture brightness is reduced. When the inductor and capacitor are resonant at a sound-carrier frequency, the volume is reduced.

Two examples are given below to illustrate this method of adjusting coils to specific inductance values. In each case, the coil is connected in parallel with a capacitor (determined from the nomograph for a given TV sound- or picture-carrier frequency) and connected in one side of the transmission line as described above.

Example 1. Using Channel-2 carrier frequencies, adjust a TVI inductor for an inductance of 0.2 μh. (a) From the nomograph, select the value of capacitance necessary for reson-

* *"The Practical Side of Building TVI Filters," by J. H. Owens, "Radio-Electronics," May,* 1952.

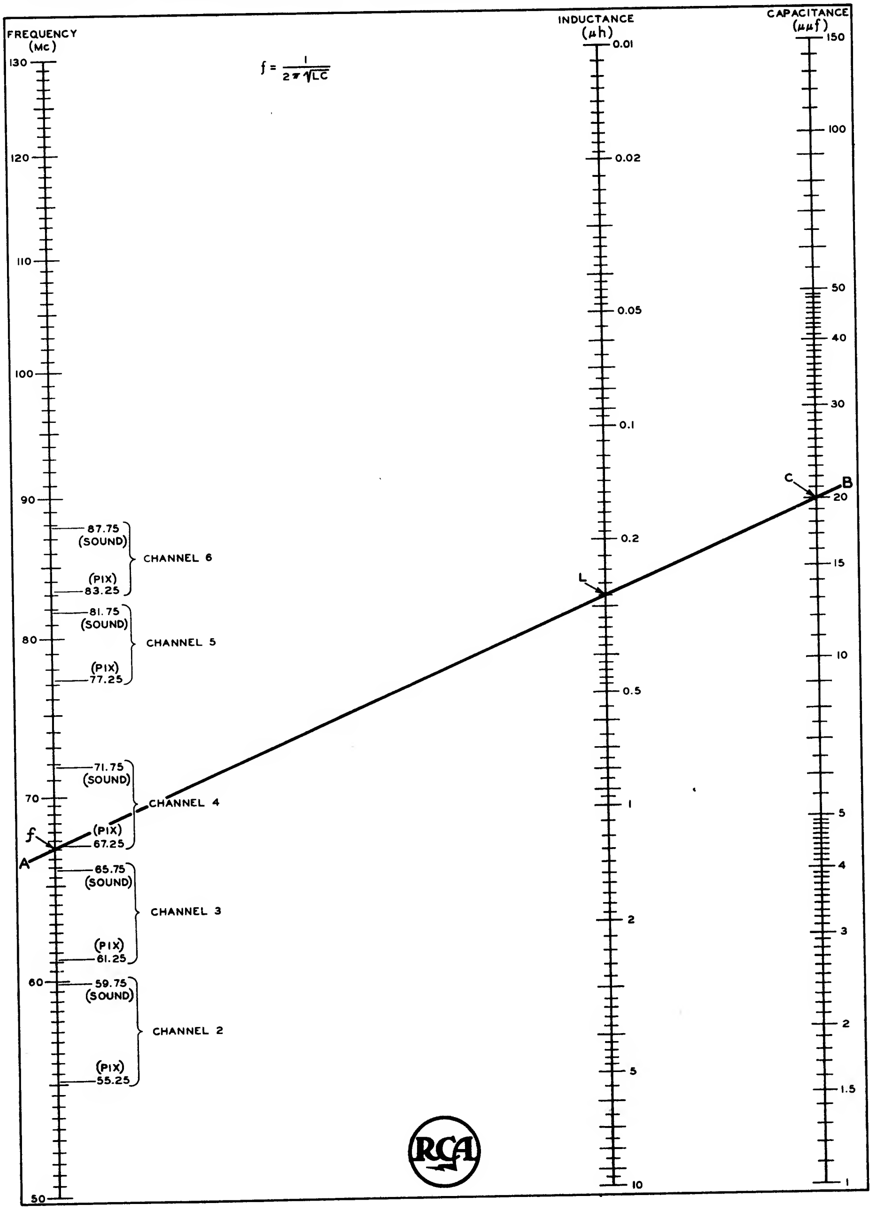
Fig. 3. Two methods of checking inductance by the resonant-circuit method. Capacitor C is a silver-mica type of known capacitance, and L is the unknown inductance.



ance with a 0.2-μh coil at 55.25 or 59.75 megacycles: (C = 41 $\mu\mu$f for the picture-carrier frequency, and 36 $\mu\mu$f for the sound-carrier frequency). (b) Compare these values of capacitance with standard values of silver-mica capacitors and select the closest available capacitor—40 $\mu\mu$f in this case. Connect the coil across the 40-$\mu\mu$f capacitor and prune the coil and vary the spacing between the turns until the Channel-2 picture brightness decreases to a minimum. The inductance of the coil will then be close enough to 0.2 μh for TVI filter applications.

Example 2. Same as *Example 1* except Channel-3 carrier frequency is used as the resonant frequency. (a) From the nomograph, select the value of capacitance necessary for resonance with a 0.2-μh coil at 61.25 or 65.75 megacycles: (C = 35 $\mu\mu$f at the picture-carrier frequency, and 30 $\mu\mu$f at the sound-carrier frequency). (b) Use a capacitance of 30 $\mu\mu$f (20- and 10-$\mu\mu$f capacitors in parallel). Prune the coil and vary the spacing between the turns until the Channel-3 sound drops to a minimum.

Fig. 4. Nomograph for determining any one of the three parameters, inductance, capacitance, or resonant frequency of a parallel resonant circuit when the other two are known. For a given frequency, f, and the desired inductance, L, the value of capacitance for the parallel circuit shown in Fig. 3 is determined by the intersection, C, of line AB and the capacitance scale.



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HAM TIPS

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Vol. 13, No. 2 June-July, 1953

A Bandpass Transmitter-Exciter Using an RCA 6146

Part I

By Richard G. Talpey, W2PUD*

Are you planning to build a new VFO, an all-band exciter, or a pi-network final? If so, we're sure that you will find it very worthwhile to read W2PUD's article before you begin. It is intended for those readers who want to build something other than a conventional transmitter.

This article differs from the usual how-to-build-it descriptive article in that it features a thorough discussion of the "groundwork" that preceded the final design. Because of the enthusiasm with which the active ham reads such a discussion, and the improbability of the average ham copying this transmitter to the last detail, this article has been divided into two parts. Part I contains a description of the transmitter; the constructional details will appear in Part II. This arrangement provides ample space for the author to expound on some very interesting ideas on the design of a modern multiband rig. A complete schematic diagram and parts list are included in Part I for those interested in getting an early start.

THE excellent performance of the RCA-6146 beam-power amplifier at high frequencies, its maximum ICAS rating of 90 watts input for cw operation, its very low driving-power requirement (0.3 watt), and the elimination of the need for special shielding make this tube the logical successor to the 807 for use in an exciter of modern design.

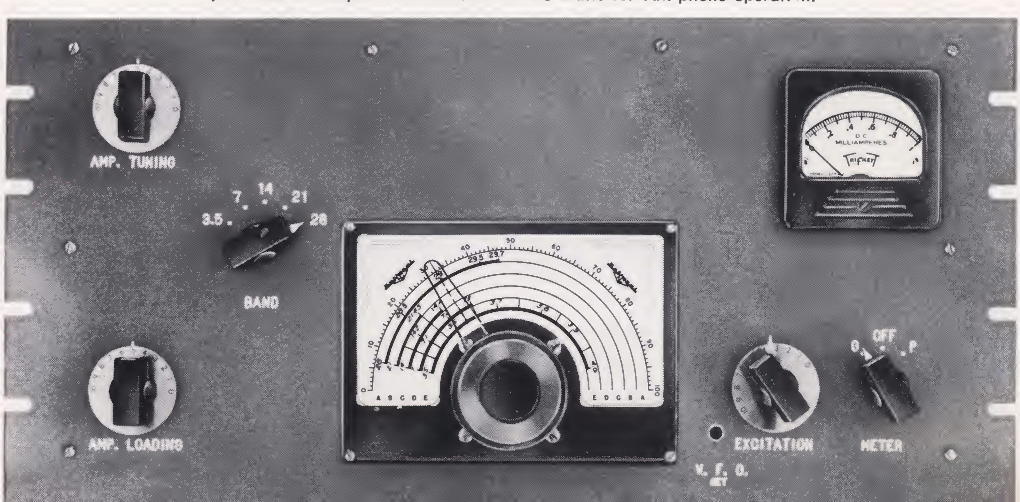
General Requirements

Early in the project, it was decided that the transmitter-exciter to be built around the 6146 should have the following features: (a) operation on the 3.5-, 7-, 14-, 21-, and 28-Mc bands by means of a single handswitch and VFO; (b) provision for break-in operation; (c) freedom from TVI; (d) reasonably simple construction; (e) minimum of tubes and controls.

The transmitter shown in *Fig. 1* provides all of these features. For ease of operation, this unit requires no tuning other than the VFO and the final tank; broadband double-tuned tank circuits are used in the exciter stages, and a tapped pi-L tank circuit provides flexible TVI-proof operation of the final am-

*Tube Dept., Radio Corp. of America, Harrison, N. J.

Fig. 1. Pick your band, set the VFO, tune and load the final, and you have an output of 65 watts cw or 45 watts for AM phone operation.



plifier. A keyed amplifier between the VFO and the first frequency multiplier eliminates any back-wave and permits full break-in operation.

An output of 65 watts cw or 45 watts AM phone is available on all bands.* Power requirements are 6.3 volts ac at 4.1 amp, 250 volts dc at approximately 100 ma for the exciter stages, and either 600 volts at 150 ma or 750 volts at 125 ma for the final amplifier. The 6146 operates well at reduced plate voltages and can be run at the full rated plate current of 150 ma.

Design Considerations

Heterodyne VFO. Keeping in mind the general requirements of the rig, the first consideration was the VFO. Initially, a heterodyne-type VFO was investigated to obtain break-in operation. This unit used an 8.5-Mc crystal beating with a VFO which tuned from 4.5 to 5 Mc to provide output over the 3.5-Mc band.

Several circuits were moderately successful, providing sufficient output and good keying in the mixer stage. Although these tests were carried out on the bench with rather haywire unshielded circuits, it was possible to eliminate the receiver backwave almost completely when the key was up. One of these circuits used a 6AK6 Clapp VFO, a 6C4 crystal oscillator followed by a 6AU6 buffer and a 5763 mixer. The 6AU6 was keyed, and a bandpass tank circuit was employed in the output of the mixer to attenuate the unwanted sideband and the two oscillator frequencies. The use of the 5763 as a mixer, however, required that an amplifer be used to bring the signal up to the proper level to drive the final on 75 meters.

The original lineup, using a 5763 amplifier/multiplier and 5763's in all of the multiplier stages, was viewed with some misgivings because the 5763 oscillated when operated as a straight-through amplifier. Various neutralization circuits were applied to the 5763 without success, the chief difficulty being the maintenance of proper phase opposition in the band-pass coupling circuits over the fairly large bandwidth of the 3.5-Mc band.

** The reader may ask why the frequency range of this transmitter does not include the 11-meter band. Considerable thought and experiment went into this possibility. In order to cover 3.3 to 4 Mc with a double-tuned circuit, the Q must be lowered to a value that makes the proper degree of coupling between coils very difficult to obtain; furthermore, the skirts of the response curve of the stage would be fairly broad. It was felt that the advantages of 11-meter operation do not justify the increased complexity or compromises in the design, e.g., an extension of the tuning range of the VFO down to 3.3 Mc results in the 14-Mc band occupying a smaller section of the dial.*

An even more serious difficulty arose when the band-pass tank circuit provided inadequate filtering thereby permitting a complex signal (containing both oscillator signals and their sidebands) to be applied to an amplifier which had to be driven hard enough to draw grid current (and thus present a non-linear impedance). Although the desired sideband was partially filtered out in the previous stage, there was sufficient voltage present at the unwanted frequencies, and the heterodyne signal which resulted from this non-linear mixing could only be characterized as a mess.

A little reflection shows that nothing other than the above results can be predicted when a high-level mixing system is used unless a filter having rigid requirements is used in the output of the mixer. (It is entirely possible to build a successful heterodyne VFO; several have already been described in the amateur-radio literature.) Mixing is best accomplished at low level, where unwanted sidebands can be filtered more easily without too much shielding.

The advantage of a mixer VFO lies mainly in the ease of keying and obtaining break-in, and in the stability which is gained by allowing both oscillators to run continuously. However, there are other ways to accomplish the same result with much simpler circuits.

Shielded VFO. The VFO finally chosen for this transmitter is one that has been in use in the author's shack for several years. The system is not novel; in fact, it has been used in several commercially-built transmitters, and has been described in the literature.* The VFO operates on 1.7 Mc. Sufficient shielding is employed so that it can be run continuously —keying is accomplished in the first amplifier stage following the oscillator.

In this system, the oscillator must be relatively free from harmonics and the design must not include any non-linear circuits between the VFO and the keyed stage. The VFO employs a Clapp oscillator which is especially suitable for this application because it is very stable; also, it is essentially a weak oscillator having a rather high Q and very little harmonic output. The particular variety of Clapp VFO chosen for this application has been described previously.** By running the oscillator at low plate voltage (40 volts) and following it with a high-gain keyed stage, it is possible to reduce the radiation to almost nil, so that the VFO may be run continuously without interference when the key is up.

** "A Solution to the Keyed-VFO Problem," by R. M. Smith, W1FTX, QST, Feb. 1950, pg. 11.*

*** "Some Notes on the Clapp Oscillator," by R. G. Talpey, W2PUD, QST, Jan. 1949, pg. 45.*

VFO and Keyed Amplifier. The complete circuit for the transmitter is shown in *Fig. 4.* The Clapp oscillator uses a single section of a 12AU7; the other section of this tube is a cathode follower which provides a low-impedance output that "can be led around the chassis" through a shielded cable to the grid of the 6AU6 keyed amplifier.

The use of a high-gain keyed amplifier makes it possible to operate the VFO with an output voltage of about 1 volt, thereby making the shielding problem easier to solve.

It was found desirable to mount the coupling capacitor and grid leak for the keyed-amplifier stage inside the oscillator shield compartment. This arrangement permits a short (¼-inch) length of signal lead to be exposed for connection to the grid of the keyed amplifier. Simple by-pass and decoupling networks in the power leads to the VFO compartment, plus the use of shielded wire for power wiring leaves little possibility for leakage from the oscillator.

The 6AU6 high-gain keyed amplifier operates close to class-A conditions. It provides good shielding and enough output to drive a 5763 (first doubler) which doubles to 3.5 Mc. Impedance coupling is used between the 6AU6 and the first doubler to reduce the number of tuned circuits.

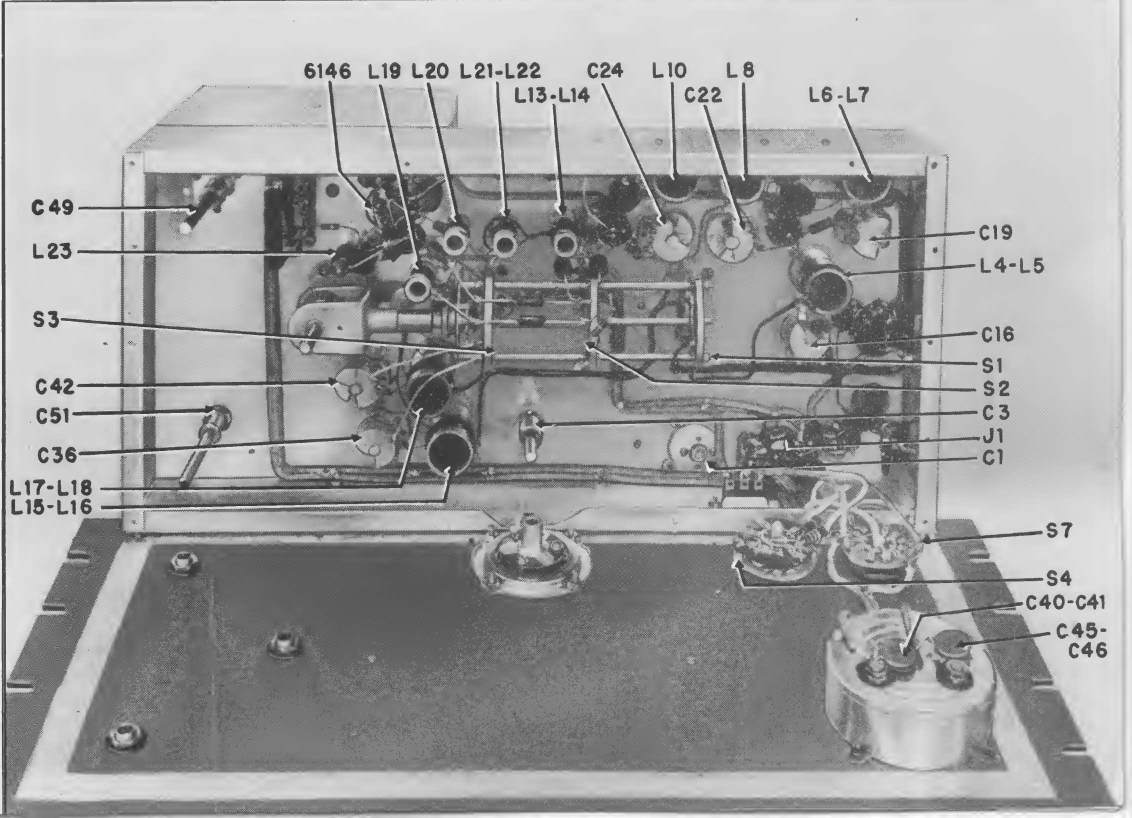
Coupling Methods For Bandpass Operation

In this transmitter, bandpass coupling circuits are used to eliminate the need for retuning the multiplier stages when the frequency of the VFO is changed. This arrangement was employed (instead of ganging the tuning controls of the multipliers with the VFO dial) to avoid a tracking problem and to minimize the number of restrictions on the physical layout of the exciter.

Broadband Tank Circuits. Although broadband resistance-loaded tanks were used in the past, they are no longer recommended because they are rather unsatisfactory for TVI reduction. The low Q's involved do not provide sufficient skirt selectivity and the possibility of transmission of several harmonics of the multiplier frequency can lead to possible misadjustments and considerable harmonic output.

Several exciters using broadband, double-tuned tanks in the multiplier stages have been described in the literature. All of these exciters employ critically-coupled or over-coupled transformers to achieve the broadband performance. The primary and secondary windings of such transformers can be wound on the same coil form or mounted close to each other with their axes parallel.

Fig. 2. Inside view of the transmitter. Note the area where the paint is removed from the panel for contact with the chassis. Also note the meter shield, the meter by-pass capacitors, and the shielded power leads—all essential TVI precautions.



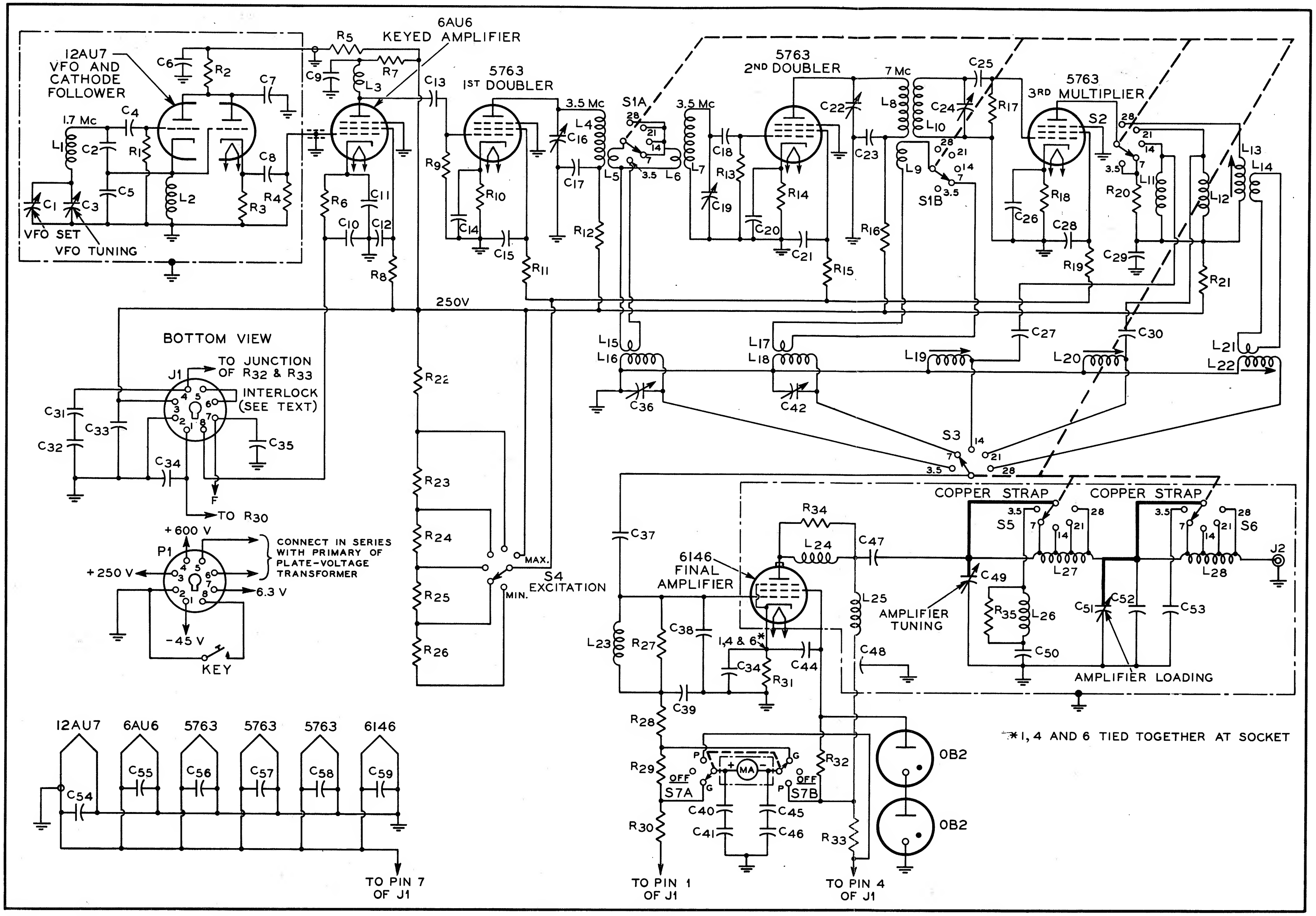


Fig. 3. Complete schematic diagram of the bandpass transmitter-exciter.

C_1, C_{22}, C_{24}, C_{25}, C_{42}	50$\mu\mu$f, midget padder (Hammarlund APC).
C_2, C_5	.001 μf, silver mica, 500 v.
C_3	30$\mu\mu$f, variable (Cardwell ET-30-ASP).
C_4, C_{37}, C_{50}	100 $\mu\mu$f, mica, 500 v.
C_6, C_7, C_9-C_{12}, C_{14}, C_{15}, C_{17}, C_{20}, C_{21}, C_{23}, C_{26}, C_{28}, C_{29}, C_{31}-C_{35}, C_{39}-C_{41}, C_{43}, C_{44}-C_{46}, C_{54}-C_{59}	.01 μf, disc ceramic, 500 v.
C_8, C_{13}, C_{18}, C_{27}, C_{30}	100 $\mu\mu$f, ceramic, 500 v (Erie GPK).
C_{16}, C_{19}, C_{36}	100 $\mu\mu$f, midget padder (Hammarlund APC).
C_{38}	25$\mu\mu$f, silver mica, 500 v.
C_{47}	.001 μf, mica, 2500 wv.
C_{48}	.001 μf, 500 v (Sprague Hypass).
C_{49}	100 $\mu\mu$f, variable, .030" spacing (Bud CE-2004).
C_{51}	300 $\mu\mu$f, variable, .024" spacing (Bud MC-910).
C_{52}	150 $\mu\mu$f, mica, 500 v.
C_{53}	470 $\mu\mu$f, mica, 500 v.
Dial	National SCN.
J_1	8-pin octal plug.
J_2	Coaxial connector (Amphenol 83-1R).
L_1	40 turns No. 24 enamel, 1½" diam, 2½" long (See text).
L_2, L_3, L_{11}, L_{12}	RFC, .5 mh (National R-50).
L_4	40 turns No. 24 enamel on National XR2 form.
L_5	3 turns No. 22 enamel—link, on same form as L_4.
L_6	3 turns No. 22 enamel—link, on same form as L_7.
L_7	32 turns No. 24 enamel on National XR2 form.
L_8	18 turns No. 22 enamel on National XR2 form.
L_9	2 turns No. 22 s.c. enamel—link, on same form as L_8.
L_{10}	22 turns No. 22 enamel on National XR2 form, mounted 1⅜" (on(centers) from L_8.
L_{13}	14 turns No. 22 enamel, spaced to occupy ¾" on Millen 69046 slug-tuned form.
L_{14}	1 turn No. 18 solid insulated—link, cemented in place over L_{13} (See text, Part II).
L_{15}	3 turns No. 22 enamel—link, on same form as L_{16}.
L_{16}	30 turns No. 24 enamel on National XR2 form.
L_{17}	3 turns No. 22 enamel—link, on same form as L_{18}.
L_{18}	14 turns No. 22 enamel on National XR2 form.
L_{19}	16 turns No. 22 enamel, spaced to occupy ¾" on Millen 69046 form.
L_{20}	10 turns No. 22 enamel, spaced to occupy ⅝" on Millen 69046 form.
L_{21}	1 turn No. 18 solid insulated—link, cemented in place over L_{22} (See text, Part II).
L_{22}	8 turns No. 22 enamel, spaced to occupy ¾" on Millen 69046 form.
L_{23}, L_{25}	RFC, 2.5 mh (National R100U).
L_{24}	7 turns No. 24 enamel wound on R_{34}.
L_{26}	7 turns No. 24 enamel wound on R_{35}.
L_{27}	19½ turns of 2"-diam, B & W 3907 coil stock, tapped at 6th, 13th, 16th and 17th turns.
L_{28}	17 turns of 1"-diam, B & W 3105 Miniductor, tapped at 4th, 10th, 13th and 16th turns.
MA	0-1 ma (Triplett 327T).

NOTE All resistors ½ watt unless specified otherwise.

R_1, R_9, R_{17}	56K.	R_{11}, R_{15}, R_{19}, R_{22}	15K, 1 watt.
R_2, R_7, R_{12}, R_{16}, R_{20}, R_{21}	1K.	R_{13}, R_{24}	27K.
R_3	2.2K.	R_{23}	18K, 1 watt.
R_4	100K.	R_{25}	33K.
R_5	47K, 1 watt.	R_{26}	220K.
R_6	220 ohms.	R_{27}	22K, 1 watt.
R_8	39K.	R_{28}	8.2K.
R_{10}, R_{14}, R_{18}	330 ohms.		

R_{29}	Meter shunt (See text, Part II).
R_{30}	560 ohms.
R_{31}	100 ohms, 5 watts.
R_{32}	30K, 10 watts.
R_{33}	Meter shunt (See text, Part II).
R_{34}	22 ohms.
R_{35}	33 ohms.
S_1-S_3	Centralab P123 Index with three type R switch sections spaced 2¼" apart.
S_4	Centralab 1401.
S_5, S_6	Centralab 2510.
S_7	Centralab 1473.

Miscellaneous

Chassis	8" x 17" x 3," aluminum (ICA 29014).
Panel	8¾" x 19," aluminum (ICA 8604).
VFO shield box	4" x 5" x 6," aluminum (ICA 29342).
Final shield box	8" x 6½" x 6" (Made from two ICA 29344 Fleximount cases and 8" x 6½" x .062" aluminum plate; See text, Part II).

When this type of transformer is adapted to a bandswitching system, either of two undesirable conditions usually arises: (1) The number of multiplier stages is increased because of the necessity of switching particular stages in or out of the lineup to obtain the correct output frequency. (2) The complexity of the switching necessitates a compromise in the physical layout.

When adjoining multiplier stages have their coils mounted close to each other (with their axes parallel), sufficient coupling can be provided if the Q's of the coupled circuits can be made high enough to obtain the proper coefficient of coupling.

Link-Coupled, Double-Tuned Coupler. If the primaries and secondaries of the tuned transformers are coupled by low-impedance links, it becomes feasible to build a broad-band exciter covering 3.5 through 28 Mc with only two or, at the most, three tubes—the usual number required for a conventional exciter.

The parts may be arranged for maximum efficiency and short leads, and the link switch may be mounted almost anywhere because it switches only low-impedance circuits.

The link-coupled, double-tuned coupler is considerably easier to adjust than the direct-coupled type because there are no large windings to be moved up and down on the coil forms. The links may be wound with stiff wire and conveniently slid over the primary and secondary windings. After the coupling

is adjusted, the links may be cemented in place.

In this transmitter, it was found convenient to use three different coupling methods; the choice of a particular coupling method for a given portion of the circuit was determined by the layout and required bandwidth.

Bandswitching the Multipliers

The grid of the final amplifier is switched to any of five resonant circuits by bandswitch S_3 and the drive is selected from the appropriate multiplier stage. The first 5763, doubling from 1.7 Mc, drives the final on 3.5 Mc. The link that is coupled to the plate circuit of this doubler is switched by S_{1A} to either the final grid circuit or the second doubler, a 5763 having its grid circuit tuned to 3.5 Mc. The output of this doubler is link coupled through switch S_{1B} to the final for 7-Mc operation.

The plate coil of the second doubler is mounted close to the 7-Mc grid coil of the third multiplier so that the two stages are coupled inductively without the use of a link circuit. This third multiplier is used to double, triple, or quadruple for output on 14, 21, or 28-Mc, respectively.

On 14 and 21 Mc, where the percentage bandwidths are small, the resonant circuit selected by S_3 functions as the tank. A choke (L_{11} or L_{12}) is used to feed plate voltage to the multiplier, and capacitance coupling is used between this multiplier and the grid circuit of the 6146.

On 28 Mc, the multiplier plate circuit is tuned by means of a slug in L_{13}, resonating with the tube capacitance. A link is run permanently to grid tank L_{22}, which is also slug tuned. Link switching is not needed here because this link is used for only one band. Switch S_2 in the plate of the multiplier selects the proper output circuit for operation on 14, 21, or 28 Mc.

The unused multipliers are left idling—a small amount of cathode bias is provided to hold the plate current at a safe value. This plate current, which is the same amount that flows when the key is up, is about equal to the operating plate current. Therefore, there is very little change in power-supply drain and no special regulation is demanded of the exciter power supply. The third multiplier, which is unused on 3.5 and 7 Mc, has a small resistor switched into its plate circuit to maintain plate voltage on the tube and to prevent the screen current from becoming excessive. A short circuit could have been used in place of the resistor, but it was felt that high-frequency parasitics might be encountered if a low-inductance plate circuit were used.

Excitation Control

Excitation to the final is controlled by adjustment of the screen voltage of the frequency multipliers. The screen grids of all the multipliers are supplied from a common bus, the voltage of which is controlled by tap switch S_4 and series resistors R_{22}-R_{26}. If it were not for the desirability of controlling the excitation to the final, the idle multipliers could be switched off when not in use, thus effecting some saving in the power drain; however, this arrangement would require two more switch sections.

6146 Bias

Grid bias for the 6146 is provided by three different means: cathode bias, a small amount of fixed bias (45 volts), and grid-leak bias. The original design contemplated the use of screen clamping of the final to eliminate the need for fixed bias. However, experience showed the combination method to be better suited to the 6146. Because of the husky cathode in the 6146, screen control is not as effective as in some other tetrodes, and ordinary clamp tubes do not reduce the plate current to a safe value when excitation is removed.

Even the use of a VR tube in series with the screen does not suffice where complete plate-current cutoff is desired. There seems to be a small amount of screen emission which allows the screen to assume a slightly positive potential, thus preventing complete cutoff. With the series VR tube and an ordinary clamp arrangement, the unexcited plate current is about 25 ma. Under this condition, the 6146 amplifies the noise generated by the high-gain multipliers and produces an annoying hiss in the receiver.

A small amount of fixed bias, conveniently obtained from a 45-volt battery (such as an RCA VS 114) obviates all this trouble, provided the screen voltage is not allowed to rise above the operating value and change the cut-off characteristic. A pair of miniature voltage-regulator tubes are used to hold the screen voltage at 210 volts when excitation is removed. These tubes may extinguish when excitation is applied and the screen current rises; however, such operation is not objectionable as long as the screen voltage is between 150 and 200 volts—high enough for efficient operation. For phone operation, it is desirable to keep the VR tubes extinguished to prevent shunting of the ac screen voltage. The value of the screen-dropping resistor is chosen to provide approximately 190 volts on the screen under normal operation; this value rises to

only 210 volts when the excitation is removed.

The stability of the final amplifier is improved materially by the use of a small mica capacitor connected directly at the socket from grid to ground. This capacitor helps to attenuate the grid harmonics and lessens the tendency toward oscillation by keeping the grid impedance low. A small amount of resistance loading is used across the grid circuit to help flatten the bandpass characteristic and to prevent the 'valley' in the overcoupled-circuit response curve from being too deep.

Pi-Network Tank Circuit

The pi-network tank circuit helps eliminate TVI and is well suited to all-band operation, particularly where bandswitching is desired. The pi network provides considerably more harmonic reduction than the parallel tank circuit without a sacrifice in amplifier efficiency. In regions where the TV signal strength is high, there is no need for additional filtering if reasonable design precautions are taken.

The network chosen for this transmitter was calculated from the curves given by Pappenfus and Klippel.* The only trouble encountered was the result of the initial assumptions. The plate impedance of the 6146, under normal operating conditions, is approximately 2,000 ohms or less—somewhat lower than that of most tetrodes. The pi network capacitances required for matching this rather low plate impedance to 50-ohm coax are fairly high if an operating Q of 15 is chosen for the 3.5-Mc band.

The importance of keeping the Q as high as this is rather dubious, particularly because it has never been adequately demonstrated that a high Q contributes materially to the reduction of higher-order harmonics when stray coupling is usually the source of most of the trouble. With a Q of 7, not low enough to reduce the amplifier efficiency, the network becomes more manageable and the values of the capacitances are reasonable. On the higher-frequency bands, the Q may be increased because the required capacitance is less.

L-Network

The complexity of the switching is not materially increased by the addition of an L network** between the pi and the antenna. The use of an L network offers two added advantages: (1) further reduction of the capacitance required to make the network fit the design curves; (2) additional harmonic attenuation. The pi network steps the impedance down to about 500 ohms, and the L network reduces it from 500 to 50 ohms. A little cut-and-try is necessary to obtain the proper taps on the inductors and the proper values of loading capacitance for the different bands if a Q meter is not available for measurement of these values beforehand. *It is well to note that the values of the loading capacitance given in the charts in the previously mentioned reference are for optimum or full load; the capacitance must be increased somewhat to provide for tuning up and lighter loading.*

A certain amount of compromise in the matter of flexibility of adjustment must be accepted in a multiband rig, because the required capacitance values vary greatly when tuning from 3.5 to 28 Mc especially where a single wide-range capacitor is to be employed. However, constants chosen for the tank provide ease of adjustment without unduly complicating the switching. On 3.5 Mc, it is necessary to switch in additional capacitance to provide proper operation without compromising the high-frequency performance.

In a complex multiband tank circuit, the use of parallel capacitances may cause high-frequency resonances and parasitics, and this case was no exception. Also, lead lengths in a bandswitching arrangement sometimes prove vulnerable to high-frequency resonances. During the bench stage of the development work on this transmitter, several rf burns were obtained from the "cold" end of the shunt capacitors before the exact nature of the parasitic resonance was recognized. However, once the parasitic paths were discovered, the judicious use of a grid-dip meter indicated where corrective measures were needed.

Because of its high power sensitivity, the 6146 cannot be expected to be free from parasitics—particularly since its high-frequency performance is so good. It is necessary, therefore, to use a parasitic choke in the plate lead and to load this choke with resistance to keep its Q low at high frequencies.

The shunt tank capacitor, C_{50}, resonating with the main variable tank capacitor on 3.5 Mc, developed a parasitic which was eleminated by the addition of choke L_{26} to the circuit. The resistance loading (R_{35}) across this small inductance introduces enough high-frequency loss to suppress the parasitic oscillation without affecting the low-frequency performance.

As a TVI precaution, the shunt padding capacitors used for both tuning and loading should be checked to make certain that they do not resonate in any of the TV channels.

(To be continued in the next issue of HAM TIPS.)

* *"Pi Network Tank Circuits," by E. W. Pappenfus, WØSYF, and K. L. Klippel, WØSQO, CQ, Sept. 1950, pg. 27.*

** *"Further Notes on Pi & L Networks," by E. W. Pappenfus, WØSYF, and K. L. Klippel, WØSQO, CQ, May 1951, pg. 50.*

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Joseph Pastor, Jr., W2KCN
Editor

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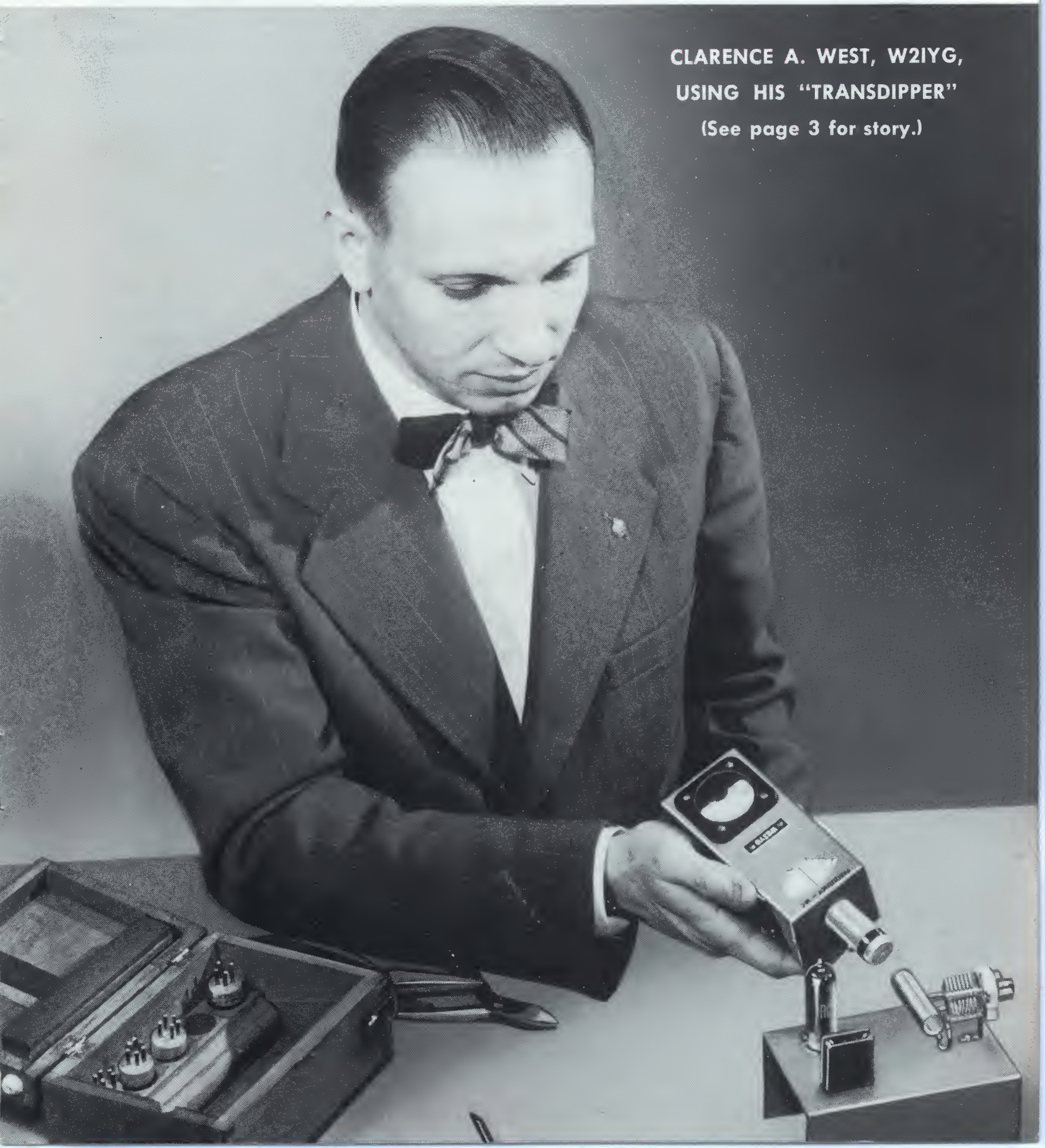


CLARENCE A. WEST, W2IYG, USING HIS "TRANSDIPPER"

(See page 3 for story.)

A Bandpass Transmitter-Exciter Using an RCA 6146

Part II

By Richard G. Talpey, W2PUD*

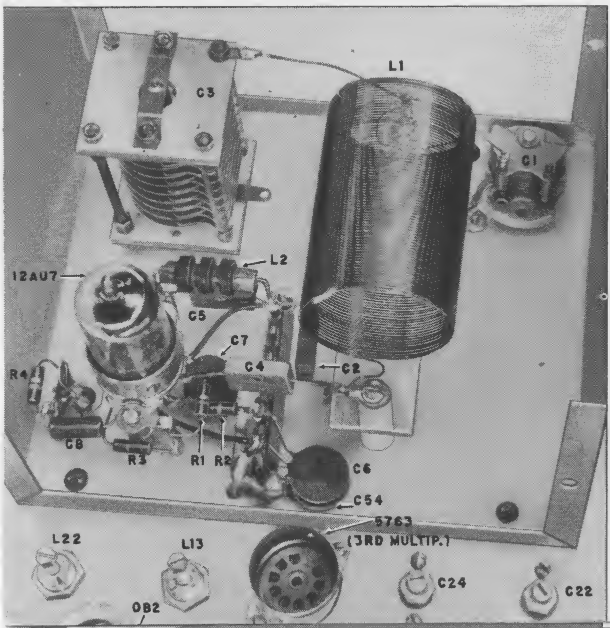
THE TRANSMITTER is built on an 8 by 17 by 3-inch aluminum chassis. The construction is somewhat unconventional inasmuch as the controls project out of the bottom of the chassis through a standard 8 ¾-inch relay-rack panel which forms the front of the shield enclosure.

The VFO is completely housed in the smaller aluminum box shown in *Fig. 1.* The larger box shields the 6146 final amplifier. The layout of the components of the VFO and the final-amplifier plate circuit are shown in *Figures 2* and *4*, respectively. Most of the other components are shown in *Fig. 3* which is a close-up view of *Fig. 2* (Part I). This method of construction permits the bandswitches to be coupled with a single right-angle drive. This arangement provides single-knob control of all bandswitches, thereby facilitating the layout.

The shield for the final-amplifier plate circuit was made from two aluminum cases (See Parts List, Part I). The unflanged portions were discarded, and the flanged sections were overlapped in the center. A sheet of aluminum was cut to fit the top.

The bandswitch is mounted in the center of the chassis so that the switch sections are located near the multiplier tubes. The bandswitch is made from a standard index assembly and separate switch sections selected according to function. A standard two-section switch for the final tank is mounted above the chassis in line with the bandswitch knob; the switches for the multipliers are coupled to the right-angle drive located inside the chassis. The other controls are placed to provide a neat panel arrangement.

Fig. I. Inside view of the VFO (with cover removed). Note that coupling capacitor C_8 and R_4, the grid resistor for the 6AU6 keyed amplifier, are located in the VFO compartment (See text).



This second and concluding part of W2PUD's article contains the constructional details and adjustment procedures. A complete description of the circuit together with a schematic diagram and parts list appeared in Part I in the June-July issue of HAM TIPS. (If you missed Part I, ask your RCA Distributor for a copy; if his supply has run out, write to RCA, Commercial Engineering, Harrison, N. J.)

VFO

The VFO coil, L_1, was wound by hand on a piece of mailing tube covered with a layer of wax paper. The wire was wound over the wax paper and spaced to occupy the required length. A few extra turns were included to allow for final trimming. A coat of household cement was applied in three longitudinal stripes 120° apart to secure the winding. A second coat was applied after the first coat hardened. The mailing tube was then collapsed and withdrawn along with the wax paper. Finally, each cement stripe was given one more coat of cement (inside and out) to make the coil rigid. After trimming, the whole coil was cemented to a ½ by 1/16-in. poly strip which was mounted on ceramic standoff insulators. This type of coil is very rugged and has the high Q required for the Clapp oscillator. The coil must be mounted as far from the sides of the shield as possible, because the shield acts like a shorted turn coupled to the coil and will reduce its Q materially if the spacing is made too small. Care should also be taken to see that the tuning capacitors and other parts cannot move with respect to the 'hot' end of the coil, which is the end connected to the capacitors.

The socket for the 12AU7 is mounted on metal spacers to permit the connectors to be made easily. All of the VFO components (as well as connections) should be made as rigid as possible because the stability of a Clapp oscillator depends to a great extent on its

* *Tube Dept., Radio Corp. of America, Harrison, N. J.*

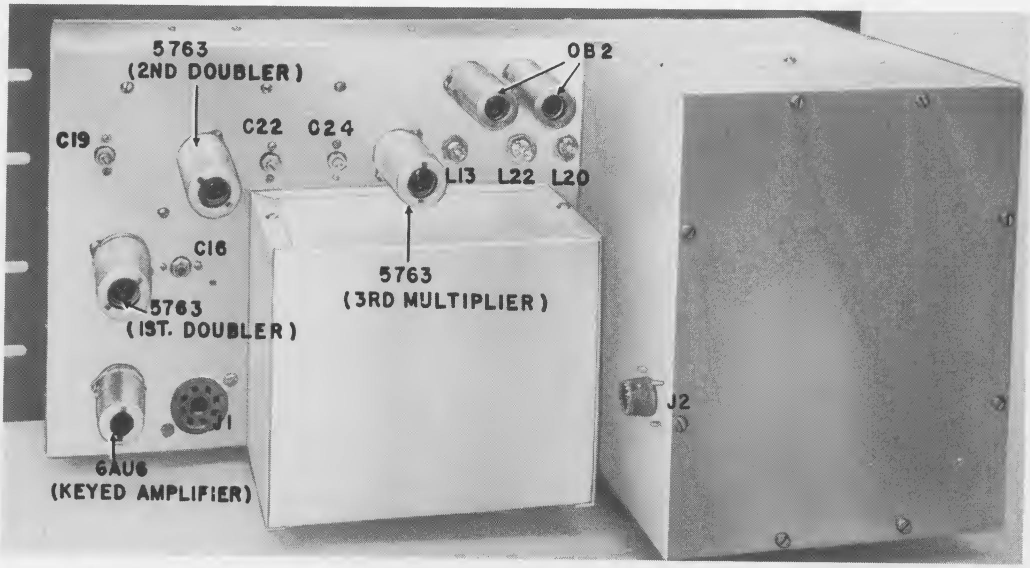


Fig. 2. Rear view of the transmitter. Complete shielding plus the pi-L tank circuit for the 6146 make this unit a "TVI-free" transmitter. The small shield box contains the VFO; the final amplifier is housed in the larger box.

mechanical construction. The grounds to the shield braids for the power leads should be made near the hole where they enter the compartment, and the by-pass capacitors should be grounded to this same point.

General Layout

As many of the holes as possible should be drilled beforehand to eliminate difficulty later on. The paint should be scraped off the back of the panel where it butts against the flange of the chassis to insure a good rf connection and to prevent rf leakage. Careful layout of the panel is required to insure that the shafts for all controls line up properly. Be sure to use panel bearings where the shafts protrude through the panel to prevent the shafts from becoming antennas for TVI. It is helpful to drill the holes for the shield cans and make a trial assembly of the shields before mounting any of the major components. Trial fits for shaft line-up for the bandswitch and tuning capacitors are also recommended.

"First-Layer" Wiring

After making certain that everything will fit where intended, the tube sockets may be mounted and the heater and power wiring started. *All grounds for each stage* are made to lugs bolted under the tube-socket lugs. Components which are not mounted directly on the tube sockets are mounted on tie lugs bolted to the sides of the chassis. All of this "first-layer" wiring is best done before assembly of the bandswitch and coils.

Power is brought into the transmitter by means of an octal socket, and all leads are by-passed at the socket to a common ground point (to which are also tied the shield braids of the power wiring). Pins 5 and 6 on power plug P_1 are connected by a jumper on socket J_1 This arrangement serves as an interlock for the external power supply by preventing application of power to the primary winding of the plate-voltage transformer when plug P_1 is removed from J_1. By-pass capacitors for the 600-volt leads are made from two 0.01-μf, ceramic-disc capacitors connected in series to provide adequate voltage rating. The by-pass capacitor for the high-voltage lead to the final-amplifier plate is a Hypass unit, mounted through a hole in the chassis and supported

COVER PHOTO

Clarence A. West, W2IYG, of the RCA Tube Department's Commercial Engineering section is shown checking the resonant frequency of a tuned circuit with the aid of his "Transdipper" — a grid-dip oscillator employing an RCA 2N33 point-contact transistor in place of the usual vacuum-tube oscillator.

Developed in W2IYG's shack, this experimental unit is believed to be the first grid-dip oscillator using a transistor and covering five amateur bands (1.7 to 33 Mc). Probably the smallest grid-dip oscillator in existence, this complete unit is housed in a metal case measuring only 5 by 2¼ by 2¼ inches. The Transdipper is powered by a self-contained 22½-volt, hearing-aid battery (an RCA VSO84).

Clarence will be remembered by many of the readers of HAM TIPS for his unusual article, "The Big Hunt (or) De-TVIing a 600-Watt, 14-Mc Transmitter," (Summer, 1951 issue) which outlines a straightforward method for eliminating TVI.

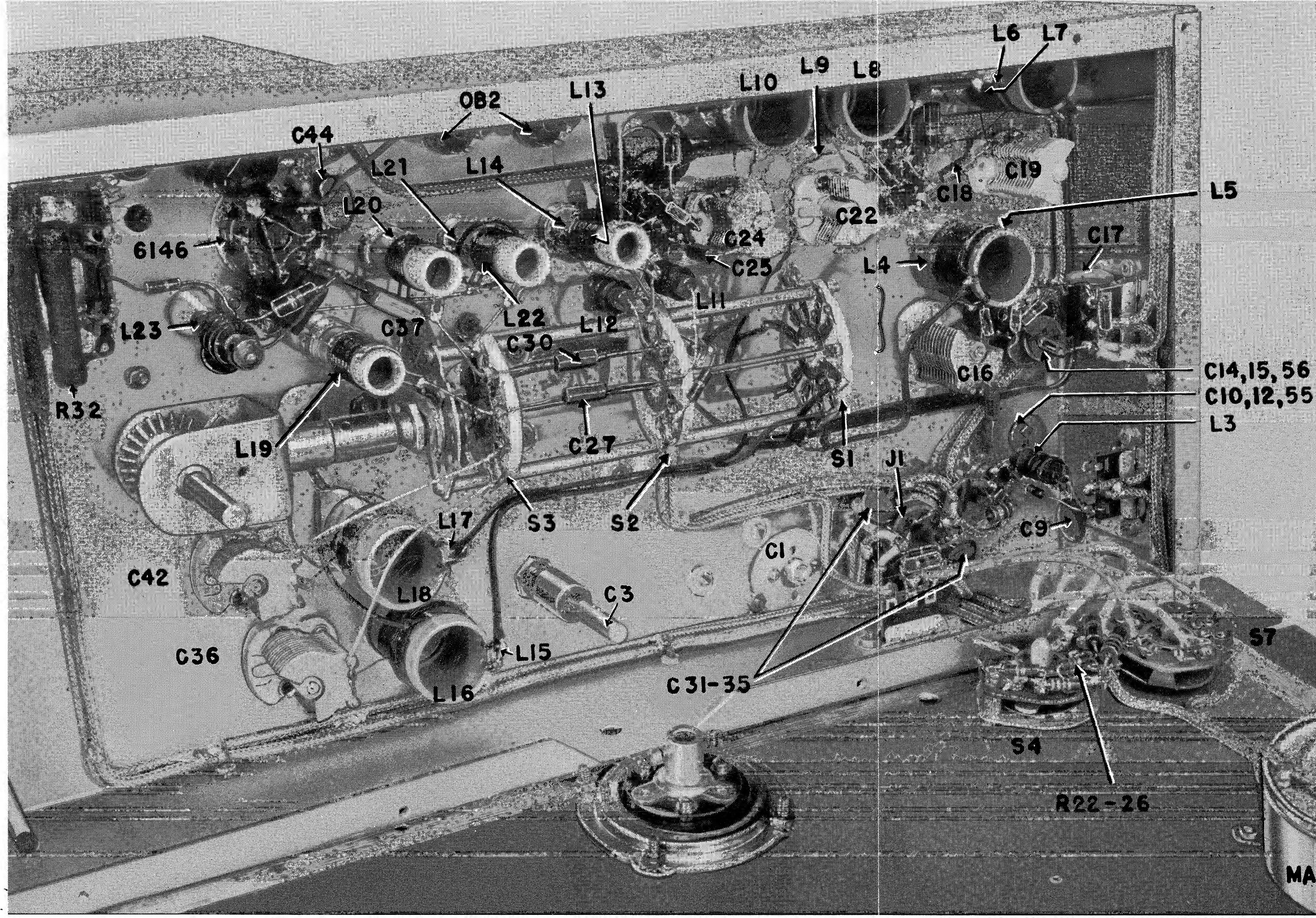


Fig. 3. Inside view of the chassis. This is a close-up of the same view shown in Fig. 2 in Part I of this article. Note that all power and heater leads are wired with shielded wire which is clamped to the chassis at convenient points.

by a small bracket as shown in *Fig. 4*.

Coils

After the preliminary wiring is completed, the bandswitch and the coils may be mounted. The coils should be wound according to the coil specifications given in the Parts List (Part I). Before they are mounted, the coils (with the exception of the link windings which will have to be adjusted later) should be given a coat of polystyrene coil dope. To obtain a high coefficient of coupling, the links are wound over a layer of cellophane tape on top of the main windings of the 3.5-Mc coils (L_4, L_5, L_{15}, and L_{16}).

All other links are wound at the "cold" end of the coils with provisions to move them slightly during line-up. Links L_{14} and L_{21} are made from a single length of No. 18 stiff, insulated wire and supported by cement on L_{13} and L_{22}, respectively, after final adjustment. Link connections to the bandswitch and between various coils are made with 75-ohm Twinlead.

Adding the VFO

After the VFO section has been constructed, it may be placed onto the main chassis at any convenient time. The output lead connects directly to the grid of the 6AU6; make certain that the portion projecting from the braid is as short as possible. Because this lead is in the low-impedance output circuit of the cathode follower, its length is not critical. Grid capacitor C_8 and resistor R_4 are placed inside the VFO shield to preclude any possibility of radiation from exposed parts.

Connections to Panel

Initially, the leads to the switches on the panel should be longer than needed so that it will be convenient to allow the panel to rest on the bench while initial adjustments are made. After the adjustments are completed and the unit is ready for "buttoning up," these leads may be shortened and connected to the switches; they should be just long enough to allow the panel to be swung out.

TVI Precautions

The rear of the meter case is covered with a shield cut from an evaporated-milk can. Fortunately, these cans are just the right size and can be easily cut with a pair of tin snips. The particular make of meter chosen (See Parts List in Part I) is slightly shorter (behind the panel) than some others and does not interfere with the coils which are mounted inside the chassis. The meter shunts, R_{29} and R_{33}, were wound with resistance wire to provide full-scale readings of 200 ma for the final plate current and 10 ma for the final grid current, respectively.

Final Amplifier

The coils for the pi network were cut from coil stock as noted in the Parts List (Part I), and no difficulty should be encountered if the taps are located as shown in the coil specifications. Coil L_{27} is mounted to the chassis by means of a small bracket which is attached to one of the plastic strips which was left a bit longer for this purpose. Coil L_{28} is supported by means of its leads, all of which are short. The output lead from L_{28} to the coax connector is shielded to reduce its inductance and to reduce stray pickup. Padding capacitors C_{50} and C_{53} are mounted between the bandswitch and ground lugs located directly underneath.

All under-the-chassis ground connections for the final amplifier are made to a lug which is mounted *on top* of the chassis and bent down through a clearance hole to receive the under-chassis leads. This arrangement *keeps all rf paths on one side of the chassis* and as short as possible. Copper strap is used for rf connections in the final amplifier to reduce inductance and keep spurious resonances at the highest frequency.

Adjustments

After the wiring has been completed, the rig is ready for lining up; the lineup may be done once and then forgotten. Remove all tubes except the 12AU7 from their sockets and test the VFO with the shield off. Adjust C_1 to set the band edge, and set C_2 for minimum capacitance to make certain that the band is covered. Some cutting of L_1 may be necessary

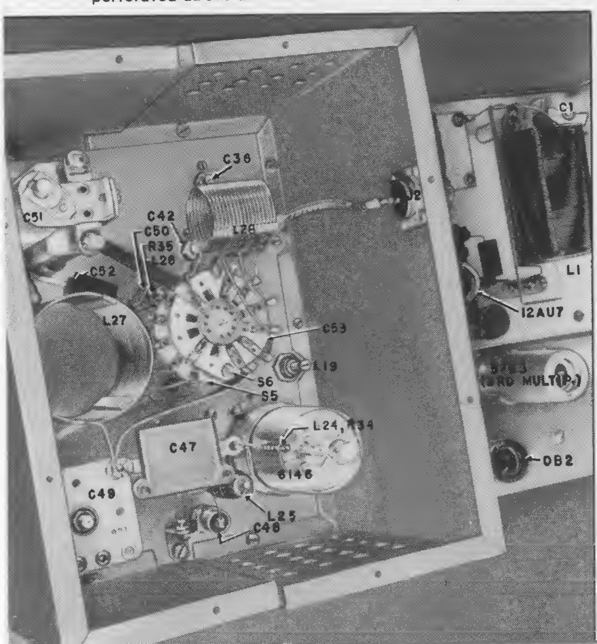
to make the band fit the dial fully. Put the shield on the VFO, and check to determine whether the VFO can be heard in the receiver. If the shield is tight and the decoupling is done properly, the VFO will not be audible.

A milliammeter should be inserted in the 250-volt lead during the lineup procedure to check plate currents. A high-resistance, dc meter such as an RCA VoltOhmyst® will be found useful for reading the rectified grid voltage, although a milliammeter wired temporarily in series with the ground end of the grid resistor will also serve the purpose. The connection between the meter and resistor should be by-passed if this latter method is used. With the 6AU6 and the first 5763 in their sockets, about 2 ma of grid current will flow in R_9 when the key is down. (Link L_5 should have its coupling reduced, and the first doubler tank should be tuned to resonance.)

Insert the 6146; with the plate voltage off and the bandswitch in the 3.5-Mc position, grid current should flow in the 6146 when the grid tank is tuned to resonance. Connect a 1,000-ohm carbon resistor temporarily across L_{16} and set the VFO to about 3.7 Mc. Slide links L_5 and L_{15} down over the coils slightly and resonate both circuits. The 1,000-ohm resistor reduces the Q of the coupled circuits to a low value, and in so doing, reduces the coefficient of coupling (dependent upon the Q). The undercoupled circuits can be peaked easily without interaction.

The grid current under this condition will be fairly small, but enough to indicate resonance. After the circuits have been tuned to resonance, remove the temporary resistor and check the grid drive over the band. It should have two peaks near the ends of the band and a valley in the center. If necessary, readjust C_{16} and C_{36} slightly so that the drive is fairly uniform over the band. A couple of tries may be necessary to obtain the right coupling between the link and the tuned circuits for the best uniformity of drive. The above procedure should be repeated each time in tuning up.

Fig. 4. Beam-power final — 1953 design! Copper strap is used to reduce lead inductance between the bandswitch and the tuning and loading capacitors. The shield box is perforated above and below the 6146 for adequate ventilation.



Next, insert the second doubler tube and turn the bandswitch to 7 Mc and set the VFO to 7.2 Mc. Connect the grid-current meter to R_{13}, and connect the 1,000-ohm resistor across L_7. Couple L_6 to L_7 and resonate the circuit with C_{19} without touching the adjustment of C_{16}. Removal of the 1,000-ohm resistor should now provide nearly uniform drive to the second doubler over the range of the VFO from 3.5 to 3.72 Mc. Again, the spacing of the links may have to be changed a couple of times to obtain the best results. The grid drive to the final amplifier through L_9 may now be adjusted by the same technique, although it will usually be unnecessary to use the 1,000-ohm resistor for the bandwidth required to cover the 7-Mc band. (The bandwidth of the circuit containing L_4 and L_7 must be broad enough to cover the 28-Mc band, whereas the plate circuit of the second doubler when coupled to the final grid need only cover 7 to 7.3 Mc.) Adjust C_{22} and C_{42} to provide uniform drive over the 7-Mc band.

Now, connect the 1,000-ohm resistor across L_{10} and resonate this circuit with C_{24} (at 7.2 Mc) with the aid of the grid meter in series with R_{17}. Do not readjust C_{22} unless it is necessary in order to make the drive to the third multiplier uniform over the range of the VFO from 3.5 to 3.7 Mc. If C_{22} has to be readjusted, go back and check the final grid drive on 3.5 Mc to be sure it has not been altered. Remove the resistor again and check the drive to the third multiplier. The location of L_{10} with respect to L_8, as given in the Parts List (Part I), should be about correct; however, this spacing may have to be changed slightly if the coils have not been wound exactly as described. L_{10} should not be closer to L_8 than is necessary for the required bandwidth for 28-Mc operation.

The difficult part of the lineup is now over and you may relax. The slugs in L_{19} and L_{20} may be adjusted to peak the final grid drive in the center of the 14- and 21-Mc bands, respectively. The 1,000-ohm resistor loading should be repeated on L_{22} and L_{13} to provide uniform drive across the 28-Mc band.

Go back and check the drive on each band and readjust wherever necessary. Then lock all capacitors and slugs. Apply a dab of cement to secure the links to the coils – you will not have to adjust these circuits until you rebuild!

Power may now be applied to the final amplifier. It is best to start at reduced plate voltage with a series resistor in the high-voltage lead. Connect a 50-ohm dummy load to the output jack with a pilot lamp across it. On any band, with C_{51} at maximum, C_{49} should be rotated to obtain a dip in plate current. The dip will be more pronounced on the higher frequency bands because the required capacitance for light loading will be less. Decreasing C_{51} will raise the plate current and the power output. Capacitor C_{49} should always be tuned for minimum plate current after C_{51} has been changed or the pi network will not behave correctly for best harmonic reduction. The presence of parasitics can be determined by reducing the fixed bias until the amplifier draws about 100 ma with the key up. Rotate C_{49} and note whether there are any changes in plate current. If there are, the amplifier is oscillating and the frequency of the parasitic oscillation should be determined with a grid-dip meter or wavemeter. During the design, the addition of L_{24} and L_{26} removed the last traces of parasitics and no tendency to oscillate was ever noted at the operating frequency.

TVI Check

With the panel and shields bolted securely, and a shielded dummy load connected to the output, no TVI was encountered with the transmitter on the bench beside a TV receiver protected with a high-pass filter. This test was made 30 miles from the TV transmitter. An inefficient TV antenna was used on the receiver which caused considerable snow on most channels. Removal of the shield from the dummy load produced crosshatching on some channels when the transmitter was operating on 14, 21, or 28 Mc. (The if amplifier in this receiver was not in the 21-Mc band!) When the 6146 plate circuit was tuned off resonance, the weak channels were obliterated – dramatic proof that the final tank must always be tuned to resonance. In regions where TV signal strength is low, a low-pass filter may be required to reduce TVI to a minimum.

Antenna Matching

The pi-L network will accommodate slight variations from the 50-ohm antenna impedance it is designed for; if the coax is not reasonably well matched, some trouble may be experienced in loading the final. A standing-wave bridge is invaluable for checking line match, either with direct feed or a line feeding an antenna tuner.

Keying

Very satisfactory keying was obtained without the use of a key-click filter. Because the multiplier stages and the final are not overbiased, no appreciable squaring of the wave shape results and the keying is clean, but not hard. If a softer note is desired, some filtering may be used provided that the cathode resistor of the 6AU6 is altered to take into account any resistance in the filter. The bias on the 6AU6 should be kept between 1 and 1.5 volts.

Modulation

The usual precautions in modulating any tetrode amplifier apply to this transmitter. The screen and plate are modulated together – about 40 watts of audio should be available. The use of a fixed screen supply for the 6146 is not recommended for phone operation.

A Few Afterthoughts

After the conclusion of such a project it is natural to wonder what possible improve-

Table of Voltages & Currents *(Typical at 7 Mc)

Tube	E_p (volts) Key Down	Key Up	I_p (ma) Key Down	Key Up	E_{g2} (volts) Key Down	Key Up	I_{g2} (ma) Key Down	Key Up	E_{g1} (volts) Key Down	Key Up	I_{g1} (ma) Key Down	Key Up
12AU7	45	45	6**	6**	—	—	—	—	—	—	—	—
6AU6	240	240	7	0	150	265	2.2	0	—	0	—	—
5763	240	240	20	17	145	180	1	1	—	-7	—	—
5763	240	240	18	19	130	170	1.5	1.5	—	-7	—	—
5763	240	220	14	19	160	180	1.0	1.2	—	-7	—	—
6146	600	650	150	10	200	210	15	—	-85	-45	3	0

* Heater voltage: 6.3 v. Supply voltages: 260 v and 600 v. ** Both sections.

ments could have been made, given the benefit of hindsight. Among these afterthoughts might be included the following:

(1) Bandspreading of the VFO to make the narrow bands easier to tune.
(2) Substitution of slug-tuned coils and fixed capacitors for the tuning capacitors in the low-frequency stages.
(3) Several changes in mechanical layout to facilitate wiring and improve the appearance. But as one who enjoys rebuilding occasionally, these changes were left for another session.

Acknowledgment

The author wishes to thank Mr. George Grammer, W1DF, for his helpful correspondence on the matter of harmonic response and Q of the pi network, and Mr. George D. Hanchett, Jr., W2YM, for his encouragement and many helpful suggestions.

Errata

There are four errors in the parts list on page 5 of the June-July, 1953 issue of HAM TIPS. L_1 should have 80 turns instead of 40; L_{28} is made from B & W 3015 Miniductor instead of 3105, and C_{48} should have a rating of 1,000 wv instead of 500 v. C_{25} should be listed with C_4, etc.

RCA TRANSISTORS NOW COMMERCIALLY AVAILABLE

The commercial availability of four RCA transistors was recently announced in an RCA Tube Department ad appearing in several trade publications.

The four types of RCA transistors announced are:

2N32—Point-contact type designed for large-signal applications such as switching circuits.

2N33—Point-contact type designed for oscillator applications up to 50 Mc.

2N34—Junction p-n-p type designed for low-frequency, low-power amplifier applications.

2N35—Junction n-p-n type designed for low-frequency, low-power amplifier applications.

Bulletins containing characteristics and technical information on these RCA transistors may be obtained by writing to RCA, Commercial Engineering, Harrison, N. J.

Because of the heavy demand for these transistors, please bear with us if your RCA distributor is out of stock.

TMK®

From your local RCA distributor, headquarters for RCA receiving and power tubes.

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Joseph Pastor, Jr., W2KCN
Editor

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HAM TIPS

A PUBLICATION OF THE TUBE DEPARTMENT · RCA · HARRISON, N. J.

Volume 13, No. 4 December, 1953

A Precision "Slick Whistle" for 3.5 to 4 Mc

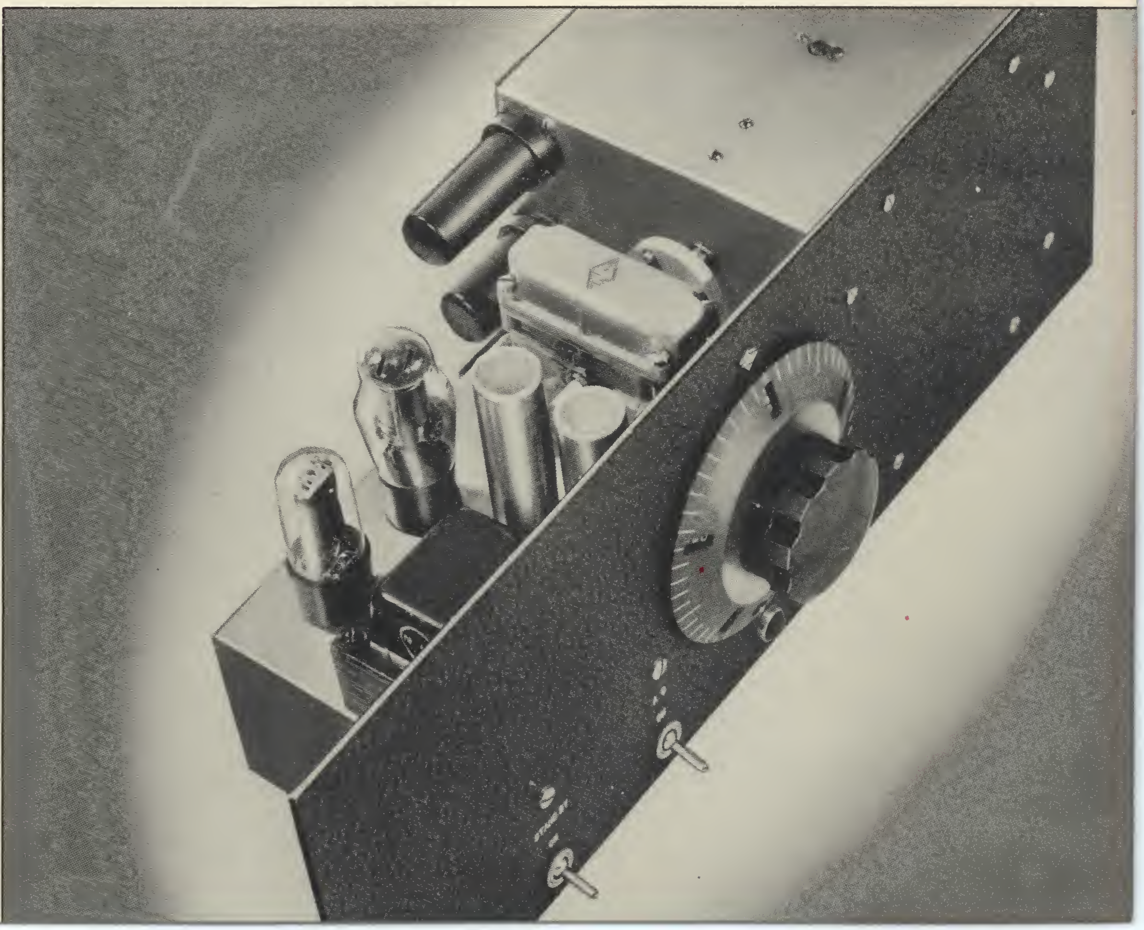
500-Kc Band Covers Approximately 500 Dial Divisions*

By F. S. Barkalow,† W2BVS

AFTER several contacts with hams who are "rock bound," one wonders why these operators handicap themselves by not employing a VFO. After receiving a few compliments on the operation of this VFO, the author asked a few of these hams why they didn't build a VFO. Most answers indicated that these hams postponed building a VFO because they assumed that frequency drift and questionable accuracy of calibration characterize all home-

* *See caption for Fig. 1.*

† *RCA Tube Dept., Harrison, N. J.*



made VFO's.

Stability and Accuracy

These were the watchwords! The VFO described in this article features rugged mechanical design plus voltage regulation to help insure frequency stability. Further assurance against frequency drift is obtained by operating this unit with its plate voltage on continuously during transmission, i.e., as a non-keyed VFO.

The problem of obtaining useful frequency calibration was solved by using a straight-line-frequency tuning capacitor together with a precision dial. Using this scheme and readily-available components, a roughly linear frequency-calibration curve has been obtained (See *Fig. 1*). Furthermore, the 500-Kc band (3.5-4 Mc) covers 497 of the 500 dial divisions. Thus, the actual frequency of the VFO (in Kc) is roughly equal to the dial reading plus 3,500.

This VFO has a high-impedance output circuit and works nicely into the crystal socket of a pentode oscillator; however, it has sufficient output to drive such tubes as an 807 or 6146 on 80 meters. For operation on 40 or 20 meters, external doubler stages are required.

General Description

The first stage employs a 6J5 in the widely used and reliable Clapp oscillator circuit. For additional output and isolation of the oscillator, a 6AG7 buffer is used. There is no tracking problem because the buffer employs an untuned tank circuit having low Q. The VFO has a conventional self-contained power supply utilizing a 5Y3-GT rectifier and an OD3 voltage regulator.

Because of the shielding provided by their metal shells, the oscillator and buffer tubes are mounted outside the oscillator box where their heat dissipation cannot affect the frequency stability. The use of silver-mica fixed capacitors, rugged, bus-bar wiring in the frequency-determining circuit, and regulated voltage on the oscillator plate and buffer screen, further contributes to the frequency stability of this unit.

Because the 500 divisions of the dial correspond to 180° of rotation, only a 180° portion of the 270° of rotation of the straight-line-frequency tuning capacitor C_2 is used. Originally, this VFO employed a tuning capacitor of the straight-line capacitance type. Substitution of the only available (locally) straight-line-frequency capacitor did pose a problem, however. The dial-shaft rotation (clockwise for an increase in number) did not correspond with the rotation of the tuning capacitor (counterclockwise for a decrease in capacitance, or increase in frequency). This problem was solved by removing the rotor and stator plates from their respective mounts and turning them over 180° and replacing them exactly in the order in which they were re-

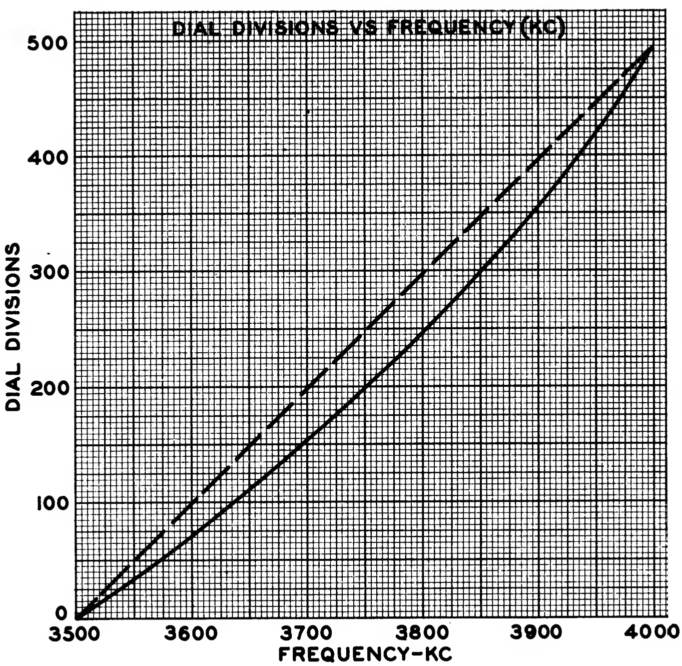


Fig. 1. Calibration curve showing frequency vs dial reading. If the calibration curve coincided with the straight line shown, the dial reading plus 3,500 would equal the VFO frequency in kilocycles. However, the dial readings have more utility than those on an arbitrary scale in that they roughly indicate the number of kilocycles above the low-frequency end of the band.

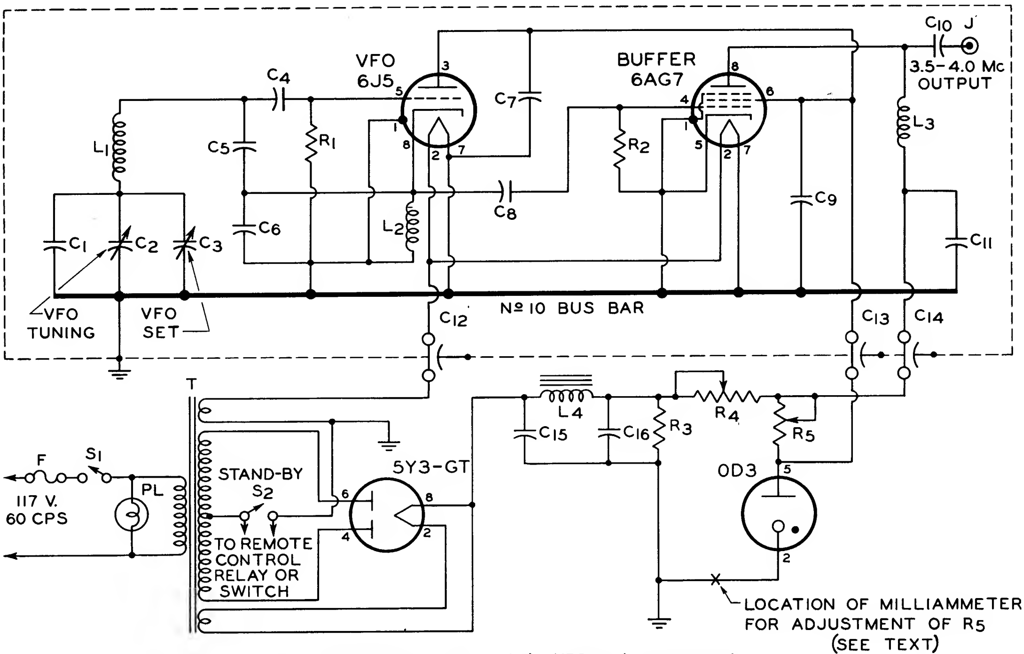


Fig. 2. Schematic diagram of the VFO and power supply.

C_1, C_4, C_8, C_{10}	100 $\mu\mu$f, silver mica (El-Menco CM-15-E-101-J).
C_2	75 $\mu\mu$f, variable (National SE75).
C_3	50 $\mu\mu$f, variable (Bud LC2079).
C_5, C_6	.001 μf, silver mica (El-Menco CM-30-102).
C_7, C_9, C_{11}	.01 μf, disc ceramic (El-Menco).
C_{12}, C_{13}, C_{14}	.0015 μf, feed through (Erie 362-152).
J	Connector (Cinch-Jones S-101).
L_1	23 turns, No. 16 enameled, spaced to occupy 2½ in., 2 in. diam (B & W 3907 coil stock).
L_2	RFC, 2.5 mh (National R-100).
L_3	RFC, 5.0 mh (National R-100).
PL	Drake No. 10.
R_1	100K, 1 watt.
R_2	50K, 1 watt.

Power Supply

C_{15}, C_{16}	16 μf, 450 wv (Cornell-Dubilier KR516A).
F	3AG, 1 amp (for Littlefuse 342001 holder).
L_4	12 h, 80 ma (Thordarson 20C53).
R_3	30K, 10 watts.
R_4	2K, 25 watts (Ohmite Dividohm 0377).
R_5	5K, 25 watts (Ohmite Dividohm 0382).
S_1, S_2	SPST, toggle, 125 v, 3.5 amp.
T	300-0-300 v, 70 ma; 5 v, 2 amp; 6.3 v, 3 amp (Thordarson T22R02).

Miscellaneous

Chassis	3" x 5" x 7," aluminum (ICA 29047).
Dial	National PW-O.
Flexible coupling	National TX9.
Panel	7" x 19," ⅛" aluminum (ICA 8603RS).
VFO shield box	6" x 6" x 6," aluminum (ICA 29843).

NOTE

The appearance of a manufacturer's name following the description of a particular component should not be interpreted as a recommendation to use that particular brand. Brand names are included only to fully identify the components which are visible in the photographs. In almost all cases, equivalent components made by other manufacturers may be substituted for those shown in this parts list.

moved. Before this modification, the pigtail wire which passed through the rotor was carefully unsoldered. *If the original plans had included the use of this capacitor, the whole layout would have been reversed, i.e., the oscillator box would be located behind the left-hand side of the panel and the power supply on the right-hand side.*

Constructional Details

There are several reasons for the unusual layout; however, the two-unit construction was decided upon mainly because it permits easy wiring within the VFO box and also because the power-supply chassis provides a convenient spot for mounting the dial gear box.

The oscillator box is a standard 6 by 6 by 6-inch item, and the power-supply chassis measures 5 by 7 by 3 inches; these are fastened to a 7 by 19-inch panel. For additional strength, the oscillator box is also fastened to the power-supply chassis by means of the bakelite block shown in *Fig. 4*. The power supply is fastened to the panel with three machine screws. One of these screws (not visible in the photograph) is located under the dial; this screw is a flat-head type. Both units are mounted on the panel after wiring. Care must be exercised in mounting the oscillator box and power-supply chassis in order to obtain perfect alignment of the gear-drive and tuning-capacitor shafts.

Careful examination of the photos will show that paint on the back of the front panel has been removed from those areas where each unit makes contact with the panel. This was done to insure a good ground connection between the units and the panel.

The special attention and care which were exercised during the construction of the oscillator box have "paid off"—the VFO produces a vibration-free note. If the oscillator components are mounted and wired while the oscillator is detached from the front panel, a much better job will result.

Vibration of leads in the frequency-determining circuit can raise havoc with the note; therefore, wherever possible, ceramic standoffs and lug terminal strips are used to strengthen the lead terminations. For the same reason, bus bar has been used for a common ground.

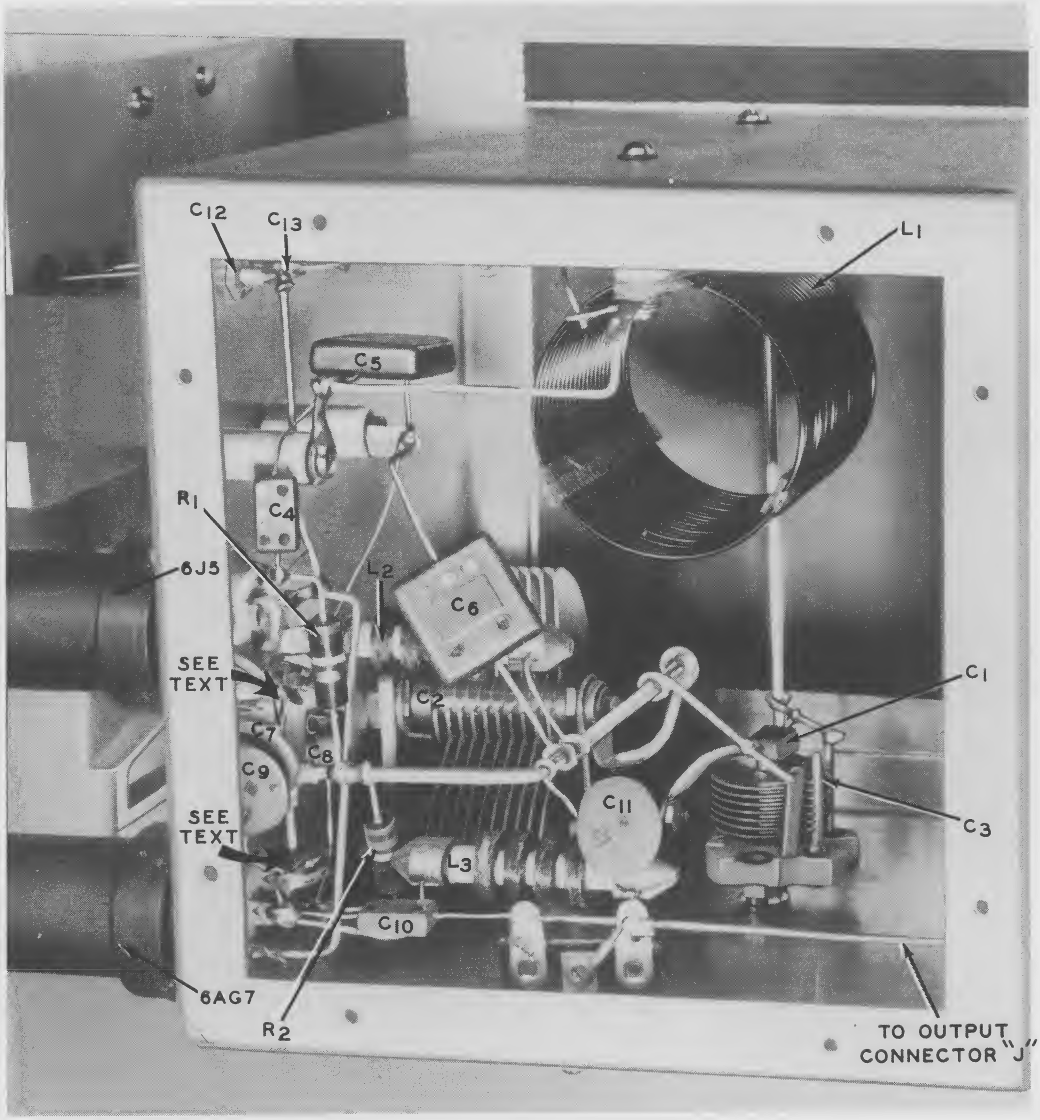
Heater and B + leads from the VFO to the power supply pass through feed-through capacitors. These capacitors are used to keep rf from feeding back to the power supply and also to prevent these connecting leads from radiating harmonics.

Line-voltage and stand-by switch connections are made through a connector on the rear apron of the power supply as shown in *Fig. 4*. This type of connector was used to conform with other connectors on the author's rack-mounted transmitter.

Wiring Procedure

A length of No. 10 bus bar serves as a common ground; it is connected to ground *only* through the rotor shaft of the tuning capacitor. All oscillator-box ground connec-

Fig. 3. Rear view of the oscillator box with the cover removed. The ground bus is bent and routed so that it functions as a common, convenient, vibrationless ground.



tions are made to this bus. The other end of this bus is supported by the heater lug of each tube socket which is to be grounded (See arrows in *Fig. 3.*). This routing of the ground bus is also clearly shown in *Fig. 3.*

The use of such a ground system eliminates ground loops which may be set up if the ground connections are made in several places on the chassis. The effect of one type of ground loop was demonstrated when an aluminum block was used (in place of the bakelite block previously mentioned) for mechanical support between oscillator box and power-supply chassis. The loop created by the addition of the aluminum block changed the calibration by approximately 20 Kc.

Connections to coil L_1, the band-set capacitor C_3, and to capacitors C_4-C_6 should be made as direct as possible and with bus bar. All other components should also be wired with short connections.

The forming and bending of the bus bar should be done before it is soldered. This procedure eliminates undue lever-action strain on lugs and terminals which would occur if bending was done after soldering one end of the bus.

Exercise reasonable care while mounting and soldering feed-through capacitors C_{12}-C_{14}. Too much pressure during the nut-tightening operation or too much heat when wires are soldered to either end of these capacitors will cause damage.

Adjustment and Calibration

Insert a milliammeter at point "*X*" in the circuit (See *Fig. 2.*) and connect a voltmeter from the junction of R_4 and R_5 to ground. Turn on the standby switch a half minute or so after the rectifier filaments have reached their operating temperature.

Alternately adjust resistors R_4 and R_5 until the voltmeter indicates approximately 280 volts and the milliammeter indicates approximately 10 ma. Use an insulated screwdriver to loosen and tighten the sliders on R_4 and R_5. *(Although it takes a little more time, for safety reasons it is advisable to turn the power switch off each time an adjustment is made.)* After these adjustments are made, remove the temporary meter connections. With these settings of resistors R_4 and R_5, the voltages on the oscillator and buffer tubes should be as follows:

6AG7 Plate— 280 volts (at 20 ma)
6AG7 Screen— 150 volts
6J5 Plate— 150 volts } (at 15 ma)

A signal source, a fairly good wavemeter, or a heterodyne frequency meter will be required to calibrate the VFO; the writer used a heterodyne frequency meter. It is preferable to do the calibrating at normal room temperature; also, it is desirable to allow the oscillator to warm up for at least 15 minutes with the stand-by switch turned on. From a cold start, the oscillator drifts about + 1 Kc; however, at the end of 15 minutes the drift is negligible.

Loosen the set screws on the dial side of the flexible coupling and, with the dial set at the first division mark, rotate C_2 to a position about one third out from the maximum-capacitance position; tighten the set screw on the coupling. With the rotor of capacitor C_3 set practically all the way out, the low-fre-

(Continued on page 7)

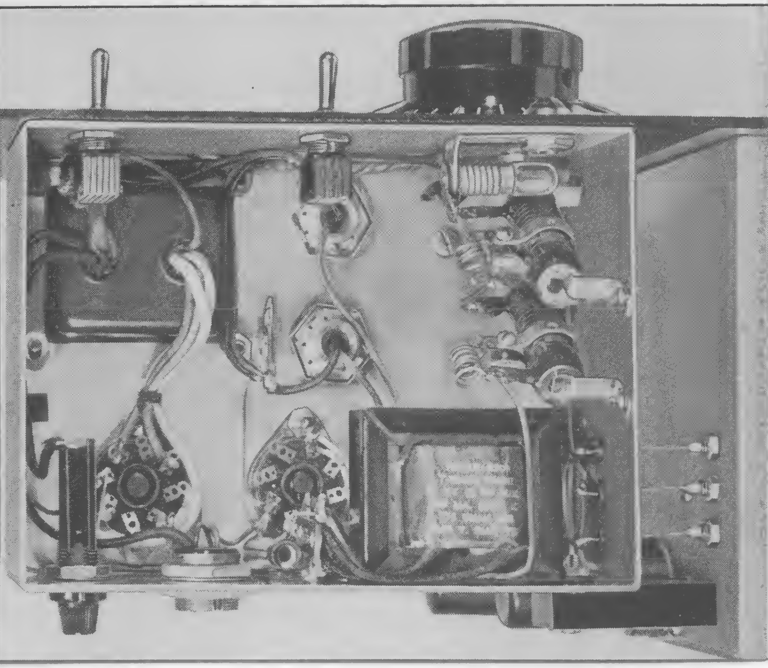


Fig. 4. Note the coiled flexible lead connecting the slider to one end of the bleeder thereby shorting out the unused resistance. Because the connection to the slider is terminated on the fixed end terminal, this arrangement prevents damage to the resistance wire by keeping the strain off the slider.

How to Determine Driver-Transformer Requirements for the Modulator

By
C. A. West,† W2IYG

After selecting the tubes and power requirements for the modulator, and the class of service for the modulator tubes and driver, the amateur is faced with the problem of selecting a suitable driver transformer for the modulator. A simple, straightforward procedure for calculating the turns ratio of the driver transformer for class AB_2 or class B service, using a few simple equations and published tube data, follows:

1. Refer to your tube manual or tube bulletin and select from the "Typical Operation" data for the driver tube (or tubes) the load resistance, R_L, for the desired value of plate voltage. For push-pull operation, the effective load resistance is given as the plate-to-plate value.

2. Determine the effective grid resistance, R_g, *of a single modulator tube* from the following approximate relation:

$R_g = \dfrac{E_g^2}{8P}$ where: E_g is the peak af grid-to-grid voltage (given in the published tube data).
P is the max.-signal driving power (given in the published tube data).

3. Substitute the values of R_L and R_g in the following formula:

† *Tube Dept., Radio Corp. of Amercia, Harrison, N. J.*

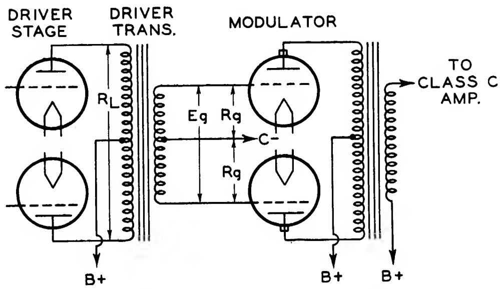


Fig. 1. For a push-pull driver stage, R_L represents the plate-to-plate load resistance. Note that R_g applies to a single modulator tube and that E_g is the grid-to-grid voltage.

$$\text{turns ratio} = \sqrt{R_L / R_g}\ .$$

If R_L is greater than R_g, the ratio is step-down; if R_L is less than R_g, the ratio is step-up. The proper impedance ratio of the entire primary winding to one-half of the secondary winding should be the same as the ratio of the load resistance, R_L, to the effective grid resistance, R_g, of a single modulator tube.

The above procedure is illustrated below:

Example. A pair of 811-A tubes have been selected to operate as class-B modulators with a plate-supply voltage of 1250 volts. The required maximum-signal driving power, P, and the peak af grid-to-grid voltage, E_g, are given in the published data (under ICAS conditions*) as 6.0 watts and 175 volts, respectively. In

* *Intermittent Commercial and Amateur Service.*

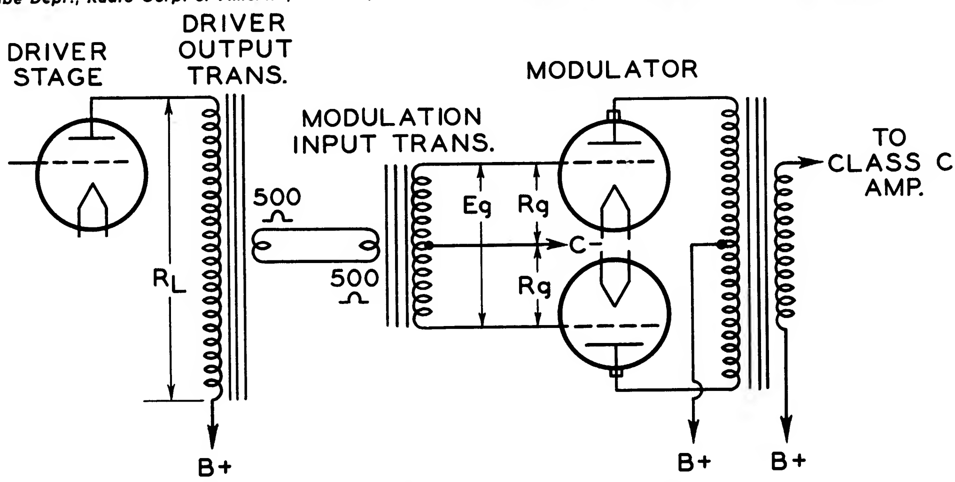


Fig. 2. If a 500-ohm line is employed between the driver stage and the modulator, 500 ohms must be substituted for R_g in the formula for the turns ratio of the driver output transformer. Similarly, 500 ohms should be substituted for R_L in the formula for the turns ratio of the modulator input transformer.

order to obtain ample driving power and to allow for circuit losses, a pair of push-pull 2A3's (operating class AB_1, with fixed bias and 300 volts on the plate) was selected to drive the modulator. The power output available from the 2A3's is approximately 15 watts.

1. The plate-to-plate effective load resistance for the push-pull 2A3's is given in the tube data as 3000 ohms.

2. The effective grid resistance of a single 811-A is

$$R_g = \frac{E_g^2}{8P} = \frac{(175)^2}{8\,(6)} = \underline{638 \text{ ohms.}}$$

3. The turns ratio of the driver transformer (full primary/one-half of the secondary) is

$$\sqrt{\frac{R_L}{R_g}} = \sqrt{\frac{3000}{638}} = \frac{2.16}{1} \quad \text{(step-down)}.$$

If a 500-ohm line is to be used between the driver stage and the modulator, the turns ratio of the driver output transformer and the modulator input transformer may be determined as follows:

1. The turns ratio of the driver output transformer (primary/secondary) is

$$\sqrt{\frac{R_L}{500}} = \sqrt{\frac{3{,}000}{500}} = \frac{2.45}{1} \quad \text{(step-down)}.$$

2. The turns ratio of the modulator input transformer (full primary/one-half of the secondary) is

$$\sqrt{\frac{500}{R_g}} = \sqrt{\frac{500}{638}} = \frac{1}{1.13} \quad \text{(step-up)}.$$

In addition to having the proper turns ratio, the transformer selected should be capable of handling the developed power. The use of a vari- or multi-match type transformer provides a wide range of impedance ratios as well as versatility for possible future modifications.

A PRECISION "SLICK WHISTLE" FOR 3.5 TO 4 Mc

(Continued from page 5)

quency end of the VFO tuning range (3,500 Kc) should fall near the first division mark on the dial. Several trial-and-error runs may be necessary to select the proper 180° portion of the tuning capacitor and the proper setting of C_3 to make the full 500 Kc of the 80-meter band cover the 500 dial divisions. If your station has more than one operator, it is a good idea to seal the final setting of C_3 with sealing wax immediately after the VFO is calibrated!

RF output at the output connector on the oscillator box was measured and found to be 45 volts rms with only a five-volt drop at the other end of the band. Connection to the transmitter should be made with unshielded wire of not more than two feet in length. The use of coaxial cable here is not recommended because its capacitance would shunt the high-impedance output of the buffer.*

Performance

The original calibration of this VFO was checked recently and found to be substantially as accurate as it was the day the curve was plotted. Time and again, schedules were kept on a pre-arranged frequency by returning to the same number on the VFO dial.

*** This VFO was installed in the transmitter relay rack. If the VFO is to be located on the operating table several feet from the transmitter, coax may be used if a cathode follower is inserted between the 6AG7 buffer and the coax. (See the first paragraph on pg. 3 of the June-July, 1953 issue of HAM TIPS.**

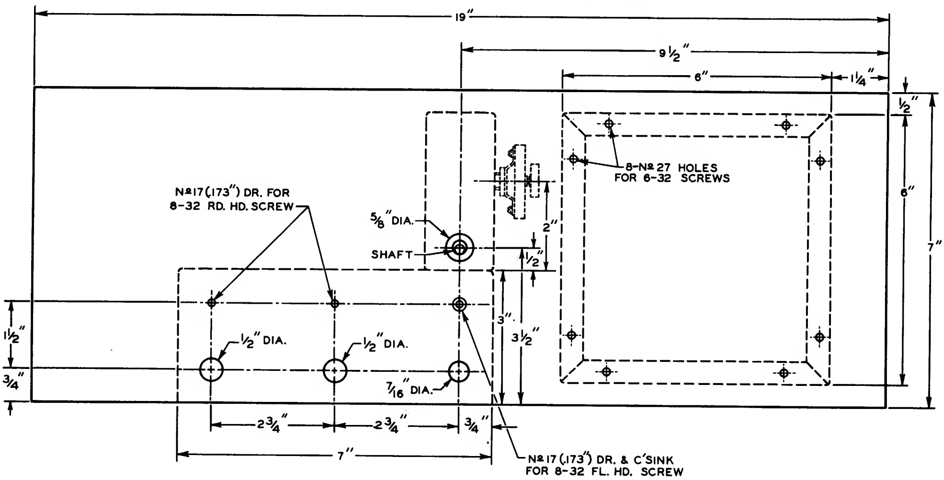


Fig. 5. Panel-layout drawing showing the location of the power-supply chassis, VFO box, and the dial gear box.

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Joseph Pastor, Jr., W2KCN
Editor

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Design Tables for Low- and High-Pass Filters for the Reduction of TVI

By Mack Seybold,* W2RYI

Many a ham who likes to "build his own" gear will admit, without any hesitation, that he doesn't get much pleasure out of building a five-section, low-pass filter for his transmitter. And for some unknown reason, the very thought of constructing a multi-section, high-pass filter for the XYL's TV set always seems to help him muster up sufficient "negative enthusiasm" to postpone such a project!

W2RYI comes to the rescue with the following set of useful filter-design tables. As in his two previous HAM TIPS articles on filters, Mack Seybold has again made the difficult seem easy. To design a filter with the aid of the tables in this issue of HAM TIPS, all you need do is look in the tables for the type of filter you want. There you will find a schematic diagram and the actual values of L and C. No formulas are given, and no calculations are required. Armed with this data and the given sample mechanical-layout drawings, you'll surely agree that the difficult part of the job is behind you—only the bench work remains!

Novices and those hams who find this article to be their first encounter with high- and low-pass filters for TVI reduction should compare the curves in *Fig. 1* with those in *Fig. 2* to determine the basic difference in the performance of these two types of filters. A low-pass filter is placed in the transmission line between the amateur transmitter and the antenna system. It is designed to pass all signals in the amateur bands below 30 Mc, and to prevent the trans-

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Fig. 1. Theoretical response curves for all of the low-pass filters in the tables. Attenuation below 45 Mc is negligible, and harmonic radiation above 54 Mc is attenuated 60 db or better, depending upon the number of sections in the filter. Complete shielding of the transmitter and filter is required to approach the response shown in these curves.

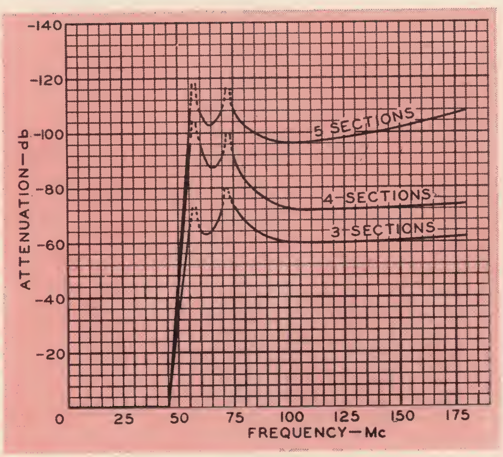
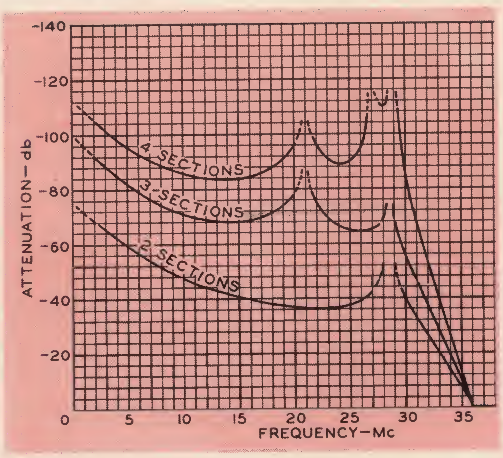


Fig. 2. Theoretical response curves for the high-pass filters in the tables. Attenuation above 36 Mc is negligible, permitting full-signal reception of television programs. Below 30 Mc, the two-, three-, and four-section filters have various attenuation peaks, and the choice for a particular installation is determined by the distance of the TV receiver from the amateur transmitter, the frequency and power of the transmitter, and the amount of filtering already present in the TV receiver.



mission of harmonics (that may be generated in the transmitter) above 45 Mc. A high-pass filter, placed in the transmission line at the "front end" of the TV receiver, does just the opposite; it passes the TV signals and attenuates all signals below 30 Mc. *Figures 1* and *2* also show the attenuation that is theoretically possible with various low- and high-pass filter structures.

Note that both series-derived filter designs and shunt-derived filters are shown in the tables. The shunt-derived, low-pass filter requires more capacitors and fewer coils than the series-derived structure.

Practical experience indicates that shunt-derived, high-pass filters have performed better than the series-derived types, probably because the signal to be attenuated comes down the feeder as a parallel standing wave and not a "transmission-line" signal; however, series-derived filters do work successfully in many installations. The latter are also easier to build and are, therefore, included in these tables.

To choose a filter design from the tables, select the configuration that matches the transmission line and produces the desired attenuation. After it has been decided what filter is best suited for the job, the values of components listed for that particular filter should be obtained from the appropriate table. The values of the components required to construct these filters are tabulated as completely-designed filters. The voltage rating for the capacitors is determined by the amount of rf to be handled. Above 200 watts input to the final amplifier of the transmitter, variable air-padder types are safest. Ceramic and mica capacitors are satisfactory for lower-powered rigs and for high-pass filters for TV receivers. Where fixed capacitors are used, select the nearest values that are commercially available and adjust the common-circuit coil inductance for the resonant frequency given in the table.

The coils for the low-pass filters can be wound with No. 12 copper wire. Directions for winding specific inductances are given in the February, 1953 issue of HAM TIPS. Coil dimensions for high-pass filters are given in the article entitled, "Design and Application of High-Pass Filters," in the Fall, 1950 issue of HAM TIPS.

Isolation of the various components (inductively and capacitively) is necessary to achieve maximum attenuation from both low-pass and high-pass filters. This isolation is accomplished by shielding as shown in *Figures 3* and *4*. If the number of sections in the desired filter is less than five for a low-pass filter or four for a high-pass filter (the maximum number in the tables) and you feel that you may later wish to increase the number of sections, choose a shield box large enough to provide an extra compartment.

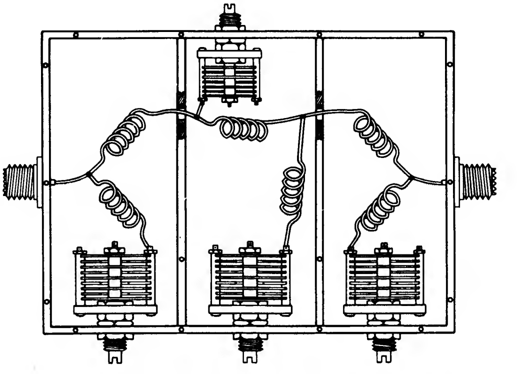


Fig. 3. Top view showing the arrangement of the parts in a three-section, series-derived, low-pass filter. The top and bottom plates of the shield box are not shown. When these plates are bolted into position, the shield box completely encloses the components. The shield box should be bolted to the transmitter cabinet where the transmission line emerges.

Other filter configurations and further details on construction are given in the articles mentioned above and in, "The Design of Low-Pass Filters," *QST*, Dec., 1949.

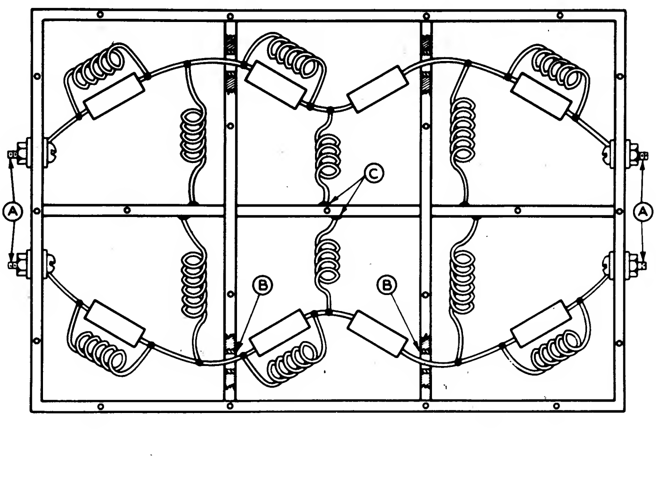
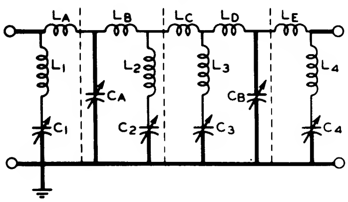
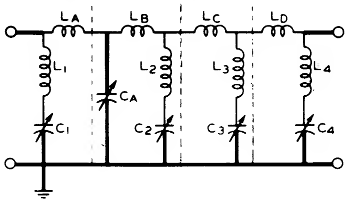


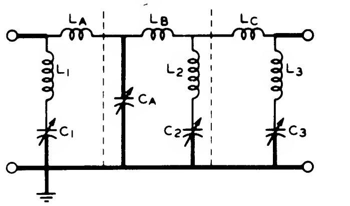
Fig. 4. Top view of a three-section, shunt-derived, balanced-line, high-pass filter. Insulated screws (A) can be used for connection to the transmission line, and insulated bushings (B) carry the connections between shielded sections. Grounded components are connected directly to the shield walls (C). The shield box should be bolted (or connected with a short copper strap) to the TV receiver chassis. Similar shielding is recommended for balanced-line, low-pass filters. High-pass filters will work without shielding, but additional sections are required to make up for the signal passed on from section to section by stray coupling.

Table I

Low-Pass Filters, Series Derived, for Coax Line (45-Mc Cut-off)







5 Sections

	Trans. Line 52 (Ohms)	Trans. Line 72 (Ohms)	Resonant Freq. (Mc)
C_1	41	29	56
L_1	0.196	0.275	
C_2	87	62	58
L_2	0.087	0.122	
C_3	106	76	71
L_3	0.048	0.067	
C_4	41	29	57
L_4	0.196	0.275	
C_A	136	97	
C_B	136	97	
L_A	0.294	0.412	
L_B	0.301	0.422	
L_C	0.261	0.365	
L_D	0.328	0.460	
L_E	0.294	0.412	

4 Sections

	Trans. Line 52 (Ohms)	Trans. Line 72 (Ohms)	Resonant Freq. (Mc)
C_1	41	29	56
L_1	0.196	0.275	
C_2	87	62	58
L_2	0.087	0.122	
C_3	106	76	71
L_3	0.048	0.067	
C_4	41	29	57
L_4	0.196	0.275	
C_A	136	97	
—	—	—	
L_A	0.294	0.412	
L_B	0.301	0.422	
L_C	0.261	0.365	
L_D	0.254	0.356	
—	—	—	

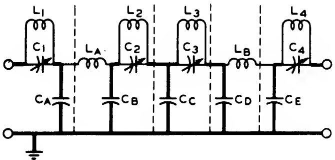
3 Sections

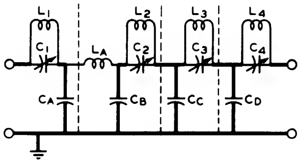
	Trans. Line 52 (Ohms)	Trans. Line 72 (Ohms)	Resonant Freq. (Mc)
C_1	41	29	56
L_1	0.196	0.275	
C_2	106	76	71
L_2	0.048	0.067	
C_3	41	29	57
L_3	0.196	0.275	
—	—	—	
—	—	—	
C_A	136	97	
—	—	—	
L_A	0.294	0.412	
L_B	0.328	0.460	
L_C	0.254	0.356	
—	—	—	
—	—	—	

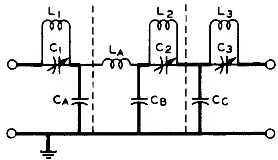
NOTE. In tables I through VII, C is in $\mu\mu f$ and L is in μh. The heavy lines represent short, low-inductance paths connecting the components. The dashed lines are shield compartment walls. (An unshielded low-pass filter is undesirable because harmonics may be radiated from the first or second section.)

Table II

Low-Pass Filters, Shunt Derived, for Coax Lines (45-Mc Cut-off)







5 Sections

	Trans. Line 52 (Ohms)	Trans. Line 72 (Ohms)	Resonant Freq. (Mc)
C_1	73	53	56
L_1	0.11	0.154	
C_2	17	12	71
L_2	0.288	0.40	
C_3	33	24	58
L_3	0.231	0.32	
C_4	73	53	57
L_4	0.11	0.154	
C_A	109	79	
C_B	124	90	
C_C	100	72	
C_D	112	81	
C_E	109	79	
L_A	0.368	0.510	
L_B	0.368	0.510	

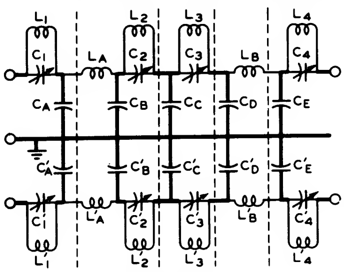
4 Sections

	Trans. Line 52 (Ohms)	Trans. Line 72 (Ohms)	Resonant Freq. (Mc)
C_1	73	53	56
L_1	0.11	0.154	
C_2	17	12	71
L_2	0.288	0.40	
C_3	33	24	58
L_3	0.231	0.32	
C_4	73	53	57
L_4	0.11	0.154	
C_A	109	79	
C_B	124	90	
C_C	100	72	
C_D	85	61	
—	—	—	
L_A	0.368	0.510	
—	—	—	

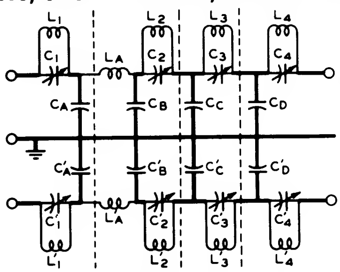
3 Sections

	Trans. Line 52 (Ohms)	Trans. Line 72 (Ohms)	Resonant Freq. (Mc)
C_1	73	53	56
L_1	0.11	0.154	
C_2	17	12	71
L_2	0.288	0.40	
C_3	73	53	57
L_3	0.11	0.154	
—	—	—	
—	—	—	
C_A	109	79	
C_B	124	90	
C_C	97	70	
—	—	—	
—	—	—	
L_A	0.368	0.510	
—	—	—	

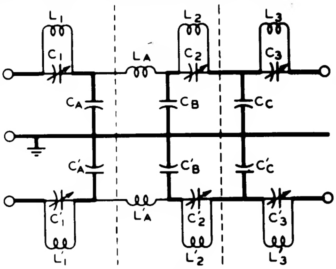
Table III Low-Pass Filters, Shunt Derived, for Balanced Line (45-Mc Cut-off)



5 Sections



4 Sections



3 Sections

5 Sections

	Trans. Line (Ohms) 100	150	300	600*	Resonant Freq. (Mc)
C_1, C'_1	75	50	25	12.5	56
L_1, L'_1	0.107	0.16	0.32	0.635	
C_2, C'_2	18	12	6	3	71
L_2, L'_2	0.275	0.415	0.83	1.66	
C_3, C'_3	33	22	11	5.5	58
L_3, L'_3	0.225	0.34	0.66	1.33	
C_4, C'_4	75	50	25	12.5	57
L_4, L'_4	0.107	0.16	0.32	0.635	
C_A, C'_A	114	76	38	19	
C_B, C'_B	129	86	43	22	
C_C, C'_C	105	70	35	18	
C_D, C'_D	117	78	39	19	
C_E, C'_E	114	76	38	19	
L_A, L'_A	0.35	0.53	1.06	2.12	
L_B, L'_B	0.35	0.53	1.06	2.12	

4 Sections

	Trans. Line (Ohms) 100	150	300	600*	Resonant Freq. (Mc)
C_1, C'_1	75	50	25	12.5	56
L_1, L'_1	0.107	0.16	0.32	0.635	
C_2, C'_2	18	12	6	3	71
L_2, L'_2	0.275	0.415	0.83	1.66	
C_3, C'_3	33	22	11	5.5	58
L_3, L'_3	0.225	0.34	0.66	1.33	
C_4, C'_4	75	50	25	12.5	57
L_4, L'_4	0.107	0.16	0.32	0.635	
C_A, C'_A	114	76	38	19	
C_B, C'_B	129	86	43	22	
C_C, C'_C	105	70	35	18	
C_D, C'_D	87	58	29	15	
—	—	—	—	—	
L_A, L'_A	0.35	0.53	1.06	2.12	
—	—	—	—	—	

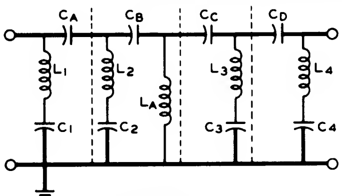
3 Sections

	Trans. Line (Ohms) 100	150	300	600*	Resonant Freq. (Mc)
C_1, C'_1	75	50	25	12.5	56
L_1, L'_1	0.107	0.16	0.32	0.635	
C_2, C'_2	18	12	6	3	71
L_2, L'_2	0.275	0.415	0.83	1.66	
C_3, C'_3	75	50	25	12.5	57
L_3, L'_3	0.107	0.16	0.32	0.635	
—	—	—	—	—	
—	—	—	—	—	
C_A, C'_A	114	76	38	19	
C_B, C'_B	129	86	43	22	
C_C, C'_C	102	68	34	17	
—	—	—	—	—	
—	—	—	—	—	
L_A, L'_A	0.35	0.53	1.06	2.12	
—	—	—	—	—	

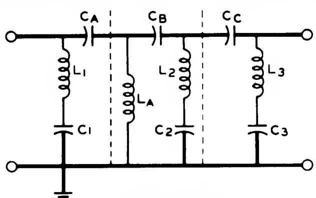
*600-ohm filters designed to cut off at 45 Mc are difficult to construct because of the low capacitance and high inductance of the components. Coils with low distributed capacitance must be employed, and care must be taken to mount the resonant sections away from shield walls.

Table IV

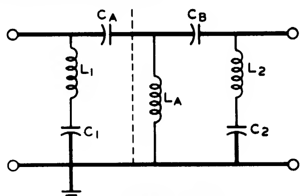
High-Pass Filters, Series Derived, for Coax Lines (36-Mc Cut-off)



4 Sections



3 Sections



2 Sections

4 Sections

	Trans. Line (Ohms) 52	72	Resonant Freq. (Mc)
C_1	79	57	29
L_1	0.38	0.53	
C_2	200	145	27
L_2	0.17	0.24	
C_3	400	290	21
L_3	0.14	0.20	
C_4	79	57	28.5
L_4	0.38	0.53	
C_A	66	48	
C_B	51	37	
C_C	47	34	
C_D	60	43	
L_A	0.11	0.16	

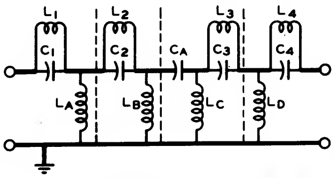
3 Sections

	Trans. Line (Ohms) 52	72	Resonant Freq. (Mc)
C_1	79	57	29
L_1	0.38	0.53	
C_2	400	290	21
L_2	0.14	0.20	
C_3	79	57	28.5
L_3	0.38	0.53	
—	—	—	
—	—	—	
C_A	53	38	
C_B	47	34	
C_C	60	43	
—	—	—	
L_A	0.11	0.16	

2 Sections

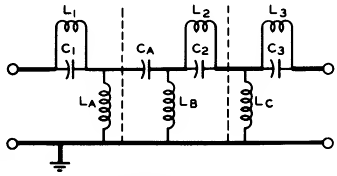
	Trans. Line (Ohms) 52	72	Resonant Freq. (Mc)
C_1	79	57	29
L_1	0.38	0.53	
C_2	79	57	28.5
L_2	0.38	0.53	
—	—	—	
—	—	—	
—	—	—	
—	—	—	
C_A	53	38	
C_B	53	38	
—	—	—	
—	—	—	
L_A	0.11	0.16	

Table V
High-Pass Filters, Shunt Derived, for Coax Lines (36-Mc Cut-off)



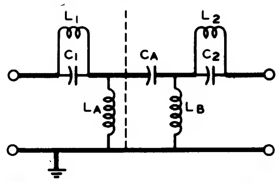
4 Sections

	Trans. Line 52 (Ohms)	Trans. Line 72 (Ohms)	Resonant Freq. (Mc)
C_1	141	102	29
L_1	0.21	0.30	
C_2	63	46	27
L_2	0.55	0.77	
C_3	52	38	21
L_3	1.09	1.51	
C_4	141	102	28.5
L_4	0.21	0.30	
L_A	0.18	0.25	
L_B	0.14	0.19	
L_C	0.12	0.17	
L_D	0.16	0.23	
C_A	42	30	



3 Sections

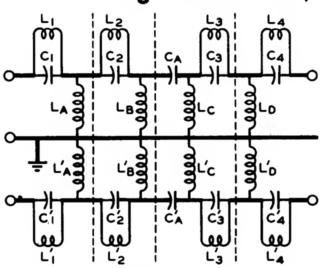
	Trans. Line 52 (Ohms)	Trans. Line 72 (Ohms)	Resonant Freq. (Mc)
C_1	141	102	29
L_1	0.21	0.30	
C_2	52	38	21
L_2	1.09	1.51	
C_3	141	102	28.5
L_3	0.21	0.30	
—	—	—	
—	—	—	
L_A	0.14	0.20	
L_B	0.12	0.17	
L_C	0.16	0.23	
—	—	—	
C_A	42	30	



2 Sections

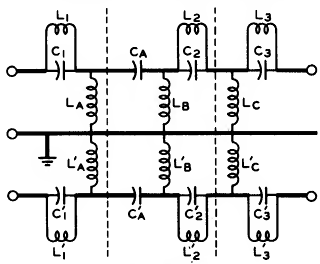
	Trans. Line 52 (Ohms)	Trans. Line 72 (Ohms)	Resonant Freq. (Mc)
C_1	141	102	29
L_1	0.21	0.30	
C_2	141	102	28.5
L_2	0.21	0.30	
—	—	—	
—	—	—	
—	—	—	
—	—	—	
L_A	0.14	0.20	
L_B	0.14	0.20	
—	—	—	
—	—	—	
C_A	42	30	

Table VI
High-Pass Filters, Shunt Derived, for Balanced Lines (36-Mc Cut-off)



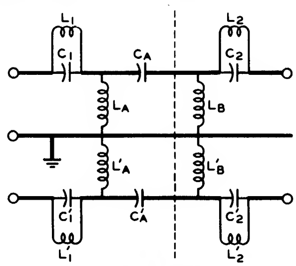
4 Sections

	Trans. Line 100 (Ohms)	Trans. Line 150 (Ohms)	Trans. Line 300 (Ohms)	Resonant Freq. (Mc)
C_1, C'_1	147	98	48.8	29
L_1, L'_1	0.21	0.31	0.62	
C_2, C'_2	66	44	22	27
L_2, L'_2	0.53	0.8	1.6	
C_3, C'_3	55	36	18.2	21
L_3, L'_3	1.05	1.57	3.15	
C_4, C'_4	147	98	48.8	28.5
L_4, L'_4	0.21	0.31	0.62	
L_A, L'_A	0.17	0.26	0.52	
L_B, L'_B	0.13	0.20	0.39	
L_C, L'_C	0.12	0.18	0.36	
L_D, L'_D	0.16	0.24	0.47	
C_A, C'_A	44	29	14.7	



3 Sections

	Trans. Line 100 (Ohms)	Trans. Line 150 (Ohms)	Trans. Line 300 (Ohms)	Resonant Freq. (Mc)
C_1, C'_1	147	98	48.8	29
L_1, L'_1	0.21	0.31	0.62	
C_2, C'_2	55	36	18.2	21
L_2, L'_2	1.05	1.57	3.15	
C_3, C'_3	147	98	48.8	28.5
L_3, L'_3	0.21	0.31	0.62	
—	—	—	—	
—	—	—	—	
L_A, L'_A	0.14	0.20	0.41	
L_B, L'_B	0.12	0.18	0.36	
L_C, L'_C	0.16	0.24	0.47	
—	—	—	—	
C_A, C'_A	44	29	14.7	

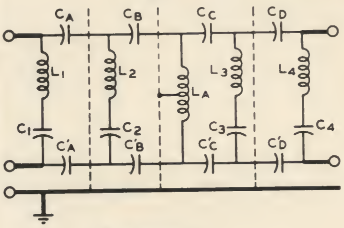


2 Sections

	Trans. Line 100 (Ohms)	Trans. Line 150 (Ohms)	Trans. Line 300 (Ohms)	Resonant Freq. (Mc)
C_1, C'_1	147	98	48.8	29
L_1, L'_1	0.21	0.31	0.62	
C_2, C'_2	147	98	48.8	28.5
L_2, L'_2	0.21	0.31	0.62	
—	—	—	—	
—	—	—	—	
—	—	—	—	
—	—	—	—	
L_A, L'_A	0.14	0.20	0.41	
L_B, L'_B	0.14	0.20	0.41	
—	—	—	—	
—	—	—	—	
C_A, C'_A	44	29	14.7	

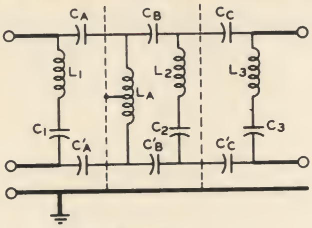
Table VII

High-Pass Filters, Series Derived, for Balanced Line (36-Mc Cut-off)



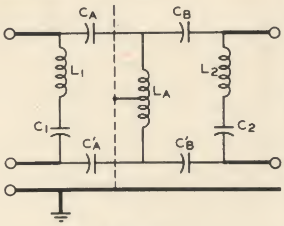
4 Sections

	Trans. Line 100 (Ohms)	150	300	Resonant Freq. (Mc)
C_1	41	27.4	13.7	29
L_1	0.73	1.1	2.2	
C_2	104	69.6	34.8	27
L_2	0.33	0.5	1.0	
C_3	210	140	70	21
L_3	0.27	0.41	0.818	
C_4	41	27.4	13.7	28.5
L_4	0.73	1.1	2.2	
C_A, C'_A	69	46	23	
C_B, C'_B	53	35.2	17.6	
C_C, C'_C	49	32.4	16.2	
C_D, C'_D	62	41.6	20.8	
L_A	0.22	0.33	0.66	



3 Sections

	Trans. Line 100 (Ohms)	150	300	Resonant Freq. (Mc)
C_1	41	27.4	13.7	29
L_1	0.73	1.1	2.2	
C_2	210	140	70	21
L_2	0.27	0.41	0.818	
C_3	41	27.4	13.7	28.5
L_3	0.73	1.1	2.2	
—	—	—	—	
—	—	—	—	
C_A, C'_A	55	37	18.4	
C_B, C'_B	49	32.4	16.2	
C_C, C'_C	62	41.6	20.8	
—	—	—	—	
L_A	0.22	0.33	0.66	



2 Sections

	Trans. Line 100 (Ohms)	150	300	Resonant Freq. (Mc)
C_1	41	27.4	13.7	29
L_1	0.73	1.1	2.2	
C_2	41	27.4	13.7	28.5
L_2	0.73	1.1	2.2	
—	—	—	—	
—	—	—	—	
—	—	—	—	
—	—	—	—	
C_A, C'_A	55	37	18.4	
C_B, C'_B	55	37	18.4	
—	—	—	—	
—	—	—	—	
L_A	0.22	0.33	0.66	

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HAM TIPS
A PUBLICATION OF THE RCA TUBE DIVISION
Vol. 14, No. 2 July-August, 1954

Components for Pi-Coupled Amplifiers

By
Mack Seybold,* W2RYI

Most of the references on this subject present data for the determination of values of the components for pi-coupled amplifiers in terms of curves or formulas. To simplify the design procedure for the amateur, W2RYI has compiled this data in easy-to-use tabular form.

The use of a pi network to couple the plate of an rf amplifier tube to the antenna provides several advantages over the use of a conventional parallel-tuned, inductively-coupled tank circuit. The ease with which a multiband transmitter employing a pi-network tank circuit with rotary or tapped coils can be operated on several bands, in addition to its harmonic-attenuation feature, has made this circuit appealing to designers of amateur transmitters. The circuit is also popular because front-panel controls can be used to compensate for reasonably large variations in transmission-line reactance.

The function of the pi network is to match a transmission line having relatively low characteristic impedance to the plate of a tube which must "see" a relatively high resistive load to produce optimum power output. *Table I* lists the estimated plate loads for the various operating conditions of several popular tubes used in amateur transmitters. To determine the plate load for a given tube type, refer to *Table I* and select the operating condition that most closely fits your requirements; the estimated plate-load value for that operating condition is given in the last column in the table. The exact load for tubes not listed in *Table I* can be determined from a set of complicated calculations; however, a good approximation can be made with the formula:

$$\text{Estimated Plate Load (ohms)} = \frac{E_b}{2I_b}$$

where E_b is the plate supply voltage, and I_b is the dc plate current in ma.

The estimated plate load is then used as the key to *Table II*. This table lists the actual values of the pi-network components for the estimated plate loads; *Fig. 1* shows the location of these components in the circuit.

Example

An RCA 6146 is to be used in a 7-Mc, cw transmitter with 750 volts on the plate, and the signal is to be fed to a 50-ohm, coaxial line. *Table I* shows the estimated plate load to be 3,100 ohms. As shown in the 3,000-ohm column of *Table II*, 7-Mc operation requires 90 $\mu\mu$f for C_1, 6.2 μh for L, and 700 $\mu\mu$f for C_2.

When a 50-ohm, non-reactive load is applied to the coax output connector, optimum loading at 7 Mc will occur with components

*RCA Tube Div., Harrison, N. J.

approximating the above values. In a practical transmitter, a capacitor of 1,000 $\mu\mu$f should be used for C_2 so that the loading can be reduced when desirable, and so that compensation can be made for variations in antenna reactance. Capacitor C_1 should be capable of tuning through resonance at 7 Mc; all variations in reactance considered, a capacitance of 150 $\mu\mu$f would be considered to be a safe design value for C_1.

Recommendations

Design and constructional details for pi-coupled finals are amply covered in the articles listed in the accompanying bibliography. These articles should be examined thoroughly for ideas and suggestions before construction is begun.

In addition to the many valuable suggestions in the literature on the design of multi-band rigs using pi-coupled finals, there are two precautions to be observed: (1) The driver should be a straight-through amplifier employing a conventional tuned tank circuit. (2) The final amplifier should not be operated as a doubler. These recommendations are important because the pi-coupled amplifier, in addition to attenuating harmonics effectively, will pass signals at frequencies below the fundamental more readily than an amplifier employing a parallel-resonant plate circuit. If the low-frequency signals from preceding multiplier stages are not permitted to reach the control grid of a pi-coupled final amplifier, successful operation will be assured.

Table I

Estimated Plate Loads for Typical Operating Conditions

Tube Type	Service	Emission	E_b volts	E_{c_2} volts	I_b ma	P_o watts	Plate Load ohms
813	ICAS	CW	2,250	400	220	375	5,100
	CCS	CW	2,000	400	180	275	5,500
	CCS	CW	1,500	300	180	210	4,200
	ICAS	Phone	2,000	350	200	300	5,000
	CCS	Phone	1,600	300	150	180	5,300
813's (Parallel)	ICAS	CW	2,250	400	440	750	2,600
	ICAS	Phone	2,000	350	400	600	2,500
807	ICAS	CW	750	250	100	54	3,700
	CCS	CW	600	250	100	40	3,000
	CCS	CW	500	250	100	32	2,500
	ICAS	Phone	600	300	100	44	3,000
	CCS	Phone	475	250	83	28	2,900
807's (Parallel)	ICAS	CW	750	250	200	108	1,900
	ICAS	Phone	600	300	200	88	1,500
6146	ICAS	CW	750	160	120	70	3,100
	ICAS	CW	600	180	150	66	2,000
	CCS	CW	600	150	112	52	2,600
	ICAS	Phone	600	150	112	52	2,600
	CCS	Phone	475	135	94	34	2,600
812-A*	ICAS	CW	1,500	—	173	190	4,300
	CCS	CW	1,250	—	140	130	4,500
	ICAS	Phone	1,250	—	140	130	4,500
	CCS	Phone	1,000	—	115	85	4,300
4-65A**	CCS	CW	1,500	250	150	170	5,000
	CCS	CW	600	250	140	54	2,100
	CCS	Phone	1,500	250	120	145	6,200
	CCS	Phone	600	250	117	50	2,500
4-125A/4D21	CCS	CW	2,500	350	200	375	6,200
	CCS	CW	2,000	350	200	275	5,000
	CCS	Phone	2,000	350	150	225	8,200
	CCS	Phone	2,500	350	152	300	6,700
4-250/5D22	CCS	CW	3,000	500	345	800	4,300
	CCS	CW	2,500	500	300	575	4,100
	CCS	Phone	3,000	400	225	510	6,700
	CCS	Phone	2,500	400	200	375	6,200
2E26	ICAS	CW	600	185	66	27	4,500
	CCS	CW	500	185	60	20	4,200
	ICAS	Phone	500	180	54	18	4,600
	CCS	Phone	400	160	50	13.5	4,600

*Grid Neutralization

**Typical operating conditions at higher plate voltages are published, but plate impedances are too high for convenient pi-network operation.

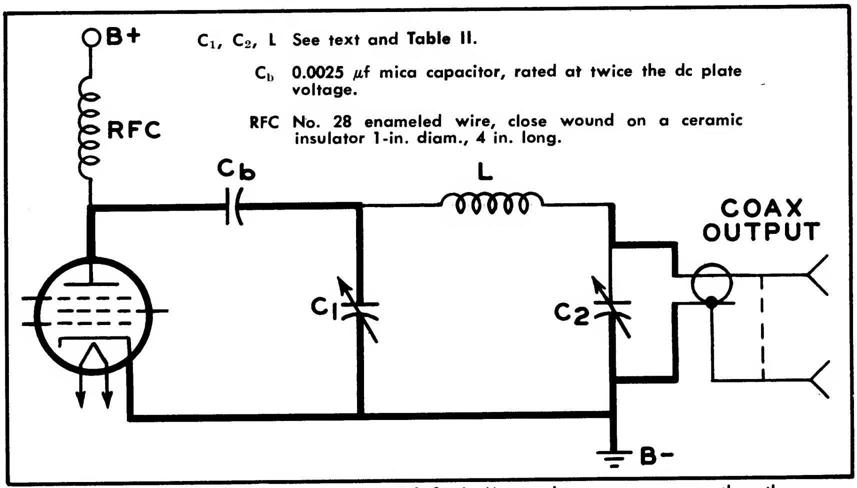

Fig. 1. Plate circuit for the pi-coupled final. Mount the components so that the connections and "chassis" paths, shown as heavy lines, will be as short as possible.

Table II Components for Pi-Coupled Final Amplifiers*

Estimated Plate Load (ohms)		1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	6,000*	NOTES
C_1 in $\mu\mu f$,	3.5 Mc	520	360	280	210	180	155	135	120	110	90	The actual capacitance setting for C_1 equals the value in this table minus the published tube output capacitance. Air gap approx. 10 mils/100 v E_b.
	7	260	180	140	105	90	76	68	60	56	45	
	14	130	90	70	52	45	38	34	30	28	23	
	21	85	60	47	35	31	25	23	20	19	15	
	28	65	45	35	26	23	19	17	15	14	11	
L in μh,	3.5 Mc	4.5	6.5	8.5	10.5	12.5	14	15.5	18	20	25	Inductance values are for a 50-ohm load. For a 70-ohm load, values are approx. 3% higher.
	7	2.2	3.2	4.2	5.2	6.2	7	7.8	9	10	12.5	
	14	1.1	1.6	2.1	2.6	3.1	3.5	3.9	4.5	5	6.2	
	21	0.73	1.08	1.38	1.7	2.05	2.3	2.6	3	3.3	4.1	
	28	0.55	0.8	1.05	1.28	1.55	1.7	1.95	2.25	2.5	3.1	
C_2 in $\mu\mu f$,	3.5 Mc	2,400	2,100	1,800	1,550	1,400	1,250	1,100	1,000	900	700	For 50-ohm transmission line. Air gap for C_2 is approx. 1 mil/100 v E_b.
	7	1,200	1,060	900	760	700	630	560	500	460	350	
	14	600	530	450	380	350	320	280	250	230	175	
	21	400	350	300	250	230	210	185	165	155	120	
	28	300	265	225	190	175	160	140	125	115	90	
C_2 in $\mu\mu f$,	3.5 Mc	1,800	1,500	1,300	1,100	1,000	900	800	720	640	500	For 70-ohm transmission line.
	7	900	750	650	560	500	450	400	360	320	250	
	14	450	370	320	280	250	220	200	180	160	125	
	21	300	250	215	190	170	145	130	120	110	85	
	28	225	185	160	140	125	110	100	90	80	65	

* Values given are approximations. All components shown in Table II are for a Q of 12. For other values of Q, use $\frac{Q_a}{Q_b} = \frac{C_a}{C_b}$ and $\frac{Q_a}{Q_b} = \frac{L_b}{L_a}$. When the estimated plate load is higher than 5,000 ohms, it is recommended that the components be selected for a circuit Q between 20 and 30.

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NEW RCA TYPE 80

The RCA type 80 full-wave vacuum rectifier was recently changed over from a size ST-14 bulb to a T-9 bulb, like that used for the 5Y3-GT. This was done in order to utilize RCA's modern tube manufacturing techniques and equipment more effectively, despite declining replacement demand for the type 80.

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Type No.	DC Plate Input (Watts)	DC Plate Volts	Plate Dissip. (Watts)	Max. Freq.* (Mc)
RCA-810	750	2500	175	30
RCA-811-A	260	1500	65	30
RCA-812-A	260	1500	65	30
RCA-833-A	1000	3300	350	30
RCA-8000	750	2500	175	30
RCA-8005	300	1500	85	60

*for Max. Plate Input and Voltage

For Class B Modulator Service (2 tubes)			Typical Operation Values	
Type No.	DC Plate Volts	Max.-Sig. DC Plate Cur. (Ma)	DC Grid Bias Volts for Max. Rating	Max.-Sig. Power Output (Watts)
RCA-805	1250	400	0	300
RCA-810	2250	450	−60	725
RCA-811-A	1250	350	0	310
RCA-812-A	1500	310	−48	340
RCA-8000	2250	450	−130	725
RCA-8005	1500	330	−67.5	330

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HAM TIPS

RCA

A PUBLICATION OF THE RCA TUBE DIVISION

Vol. 14, No. 3 December, 1954

Determination of Typical Operating Conditions for RCA Tubes Used as Linear RF Power Amplifiers

By A. P. Sweet*

During the past several years, there has been a tremendous increase in the use of single-sideband, suppressed-carrier transmission in amateur-radio radiotelephony. This type of transmission offers several advantages over the widely-used amplitude modulation methods. These advantages include reduced band-width and the elimination of heterodyne-interference problems. More useful power can be obtained with the same tubes and power supplies or, conversely, smaller tubes and power supplies can be used to deliver the same useful power.

With high-level amplitude modulation, a carrier and two groups of sideband frequencies are generated. The total power in the two sidebands at 100 per cent modulation is equal to one half of the carrier power. Thus, for every 100 watts of total transmitted power, 67 watts is in the carrier and 16.5 watts is in each sideband. Yet, one sideband contains all of the necessary intelligence for communication (provided certain receiver requirements are met).

Half the Bandwidth

Single-sideband, suppressed-carrier transmission utilizes only one sideband. By the elimination of the other sideband, the bandwidth is cut in half. By suppression of the carrier, heterodyne interference is eliminated. Only 16.5 watts of power is required to convey the same intelligence. Conversely, if the original 100 watts of power is transmitted in a single sideband, six times the former useful power will be obtained.

The literature contains considerable information on various methods of generating single-sideband, suppressed-carrier signals. However, little information is available on the choice of tubes for amplifying these signals and the methods of calculating typical operating conditions for these tubes.

Linear RF Amplifiers

Single-sideband signals must be amplified by linear rf amplifiers. These amplifiers are identical to af power amplifiers except that resonant tank circuits are used in the grid and plate circuits instead of audio-frequency transformers. Consequently, the tube manufacturer's ratings for af power amplifier and modulator service for class A, AB_1, AB_2, and class B and typical operating conditions will apply, provided the tube is also capable of operating at the higher frequencies involved. The same derating factors for plate voltage and input versus frequency shown by the manufacturer for class-C telegraphy ratings should be applied to single-sideband operation at the frequencies where they become applicable.

Because the tank circuits act as energy-storage systems, it is not necessary (as in case of audio work) to use two tubes in push-pull in class-AB or class-B, linear, rf amplifiers. However, if only one tube is used, the rf harmonics will be higher thereby making the TVI problems more severe.

Although the manufacturer's ratings are based on 100 per cent modulation with sine-wave signals, normal voice modulation reaches this condition only on the peaks of modulation. The ICAS ratings shown by RCA have

** Power Tube Engineering, Lancaster, Pa.*

taken this factor into account. Consequently, no attempt should be made to operate above these maximum ratings. Such operation will result in shorter tube life and the possibility of early tube damage during transmitter adjustment or unexpected overloads such as microphone "howl."

Since only rf power amplifiers are being considered, class A operation will not be discussed further. Of the remaining classes, AB_1 operation with tetrodes or pentodes is the simplest since only the plate- and screen-voltage supplies require good regulation.

Table I includes the maximum ratings and typical operating conditions for several RCA tubes used as linear rf power amplifiers. If it is desired to operate at conditions other than those given, typical conditions can be calculated by means of the following procedure:

1. Make sure E_b is within tube ratings.
2. Refer to the published curves. On the average plate characteristics curves, select a point on the zero grid-voltage curve near the "knee," and record i'_b,* and e_{bmin}; from the average screen-grid characteristics curves, determine i'_{c2} for this point.
   (E_{c2} equals the value shown for the curves used.)
3. Calculate I_{bms}: $I_{bms} = i'_b/3$.
4. Calculate PD:
   $$PD = \frac{I_{bms}}{4}(E_b + 3e_{bmin}).$$
5. Calculate SI: $SI = E_{c2}i'_{c2}/4$.
6. Calculate PI: $PI = E_bI_{bms}$.
7. Check the values found in steps 4, 5, and 6 to determine whether they are within tube ratings. Normally, they will be within ratings for AB_1 operation. If they are not, a lower value of i'_b (either in the negative-grid region or at a lower screen voltage) must be selected and steps 2 through 7 repeated.
8. Calculate PO: PO = PI − PD.
9. Calculate I_{bo}: $I_{bo} = I_{bms} / 5$.
10. E_{c1} can now be found on the plate characteristics curves as the grid voltage where the plate voltage is E_b and the plate current is I_{bo}.
11. $E'_g = [E_{c1}] + e_{cm}$.
    This value of E_g is the absolute value of E_{c1} (the brackets mean ignore the sign) plus the algebraic value of e_{cm} (include the sign). If the original point in step 2 was selected on the zero grid-voltage curve, then e_{cm} is equal to zero and
    $$E'_g = [E_{c1}].$$
12. Calculate I_{c2}: $I_{c2} = i'_{c2}/4$.
13. Calculate DP: $DP = \frac{E'_g i'_{c2}}{2}$ (for AB_1 operation, i'_{c1} = O so DP is zero).

*

E_b	*Dc plate voltage.*
e_{bmin}	*Minimum plate voltage for the required peak current (from the characteristics curves).*
E_{c2}	*Dc screen voltage.*
E_{c1}	*Dc control grid voltage.*
e_{cm}	*Maximum grid-voltage drive to obtain the required peak plate current at a given minimum plate voltage.*
E'_g	*Peak value of grid-voltage swing.*
I_{bms}	*Maximum-signal, dc plate current.*
I_{bo}	*Zero-signal, dc plate current.*
i'_b	*Instantaneous peak plate current.*
I_{c2}	*Maximum-signal, dc screen current.*
i'_{c2}	*Instantaneous peak screen current.*
i'_{c1}	*Instantaneous peak grid current.*
PD	*Plate dissipation at maximum signal.*
PI	*Plate power input at maximum signal.*
PO	*Power output at maximum signal.*
DP	*Driving power at maximum signal.*
SI	*Screen input at maximum signal.*

Class-AB_2 Tetrode or Class-B Triode Operation

Class-AB_2 tetrode and class-B triode operation provide more power than class-AB_1 operation, but have the disadvantage of placing stiffer requirements on the driver and grid-bias supply regulation.

Calculation of typical operating conditions other than those given in the tube data sheets is slightly more complicated for class-AB_2 and class-B operation than for class AB_1, but is still relatively simple with the procedure outlined below:*

1. Make sure E_b is within tube ratings.
2. Assume a value of I_{bms}. A good starting point is at
   $$I_{bms} = \frac{3\ (\text{rated PD})}{E_b}.$$
   Check this value to see whether it is within ratings. If it is not, use the maximum rated value of I_{bms}.
3. Calculate i'_b: $i'_b = 3I_{bms}$.
4. From the plate characteristics curves, select a value of e_{bmin} near the "knee" of the curves at which i'_b can be obtained. Also record E_{c2}, e_{cm}, i'_{c1} and i'_{c2} for this point.
5. Calculate PD:

* *Calculation for tetrodes is discussed; the triode case is the same except for the omission of the calculation of screen-input power.*

$$PD = \frac{I_{bms}}{4}(E_b + 3e_{bmin}).$$

6. Calculate SI: $SI = \frac{E_{c2}i_{c2}}{4}$

7. Calculate PI: $PI = E_b I_{bms}$.

Check the values found in steps 5, 6, and 7 to determine whether they are within the maximum ratings for the tube type. If the calculated values exceed the maximum ratings, choose a lower value of I_{bms} and repeat steps 3 through 7.

If the plate dissipation and input are below the maximum ratings but the screen input is high, it may be possible to choose a higher value of e_{bmin} in step 4 (and repeat steps 5, 6, and 7) to get all values within ratings. The reverse case can also be applied.

If all the values are well below maximum ratings, a higher value of I_{bms} can be chosen in step 2, and steps 3 through 7 repeated to see whether the operation is still within ratings. If so, this latter set of operating conditions will provide slightly more power output.

When values that are slightly below the maximum ratings are obtained for plate dissipation, screen input, and plate input,, the corresponding value of I_{bms} represents the maximum value which can be used at the original plate voltage selected. Lower values of I_{bms}, which give more conservative operation but less power output, can also be used.

Once the value of I_{bms} is selected, the remainder of the calculation follows steps 8 through 13 shown for class AB_1 operation. The driving power (DP) calculated does not include the rf tube and circuit losses. Consequently, for adequate performance, at least ten times this value of power should be available from the driver.

The following example illustrates the calculation of "typical operation" conditions for the class-AB_2, CCS operation of the type 807 with an E_b of 600 volts:

1. The maximum plate voltage rating is 600 v.
2. Determine I_{bms}:

$$I_{bms} = \frac{3\ (\text{rated PD})}{E_b} = \frac{3\ (25)}{600} = .125 \text{ amp.}$$

This value is above the maximum-signal, dc plate-current rating (from tube handbook or tube bulletin); therefore, the maximum rated value of 120 ma will be used as a first approximation.

3. $i'_b = 3I_{bms} = 3\,(120) = 360$ ma.
4. From the 300-v E_{c2} curves, *Fig. 1,* select $e_{bmin} = 90$ v, and read e_{cm} $(= +\ 12$ v). From *Figures 2* and *3,* read $i'_{c1} = 12$ ma, and $i'_{c2} = 35$ ma, respectively.

5. $PD = \frac{I_{bms}}{4}[E_b + 3(e_{bmin})]$

$$= \frac{120}{4}[600 + 3(90)] = 26 \text{ w.}$$

6. $SI = \frac{E_{c2}i_{c2}}{4} = \frac{300(.035)}{4} = 2.6$ w.

7. $PI = E_b I_{bms} = 600\,(.120) = 72$ w.

PD and PI are both above ratings, and a lower value of e_{bmin} at the required current cannot be found on the curves. Therefore, a lower value of I_{bms} must be chosen; try a value of 100 ma, and repeat steps 3 through 7:

3. $i'_b = 3\ (100) = 300$ ma.
4. From the 300-v E_{c2} curves: $e_{bmin} = 70$ v, $e_{cm} = +\ 7$ v, $i'_{c1} = 8$ ma, $i'_{c2} = 35$ ma.

5. $PD = \frac{.100}{4}[600 + 3(70)] = 20.3$ w.

6. $SI = \frac{300(.035)}{4} = 2.6$ w.

7. $PI = 600\ (.100) = 60$ w.

These values are within ratings; therefore, the remainder of the calculations can be completed:

8. $PO = PI - PD = 60 - 20.3 = 39.7$ w.

9. $I_{bo} = \frac{I_{bms}}{5} = \frac{100}{5} = 20$ ma.

10. E_{c1} (from *Fig. 1*) $= -35$ v.

11. $E'_g = [E_{c1}] + e_{cm} = 35 + (+7) = 42$ v.

12. $I_{c2} = \frac{i'_{c2}}{4} = \frac{35}{4} = 8.7$ ma.

13. $DP = \frac{E'_g i'_{c2}}{2} = \frac{42(.008)}{2} = .17$ w.

These values compare reasonably well with the published values.

(Continued on Page 5)

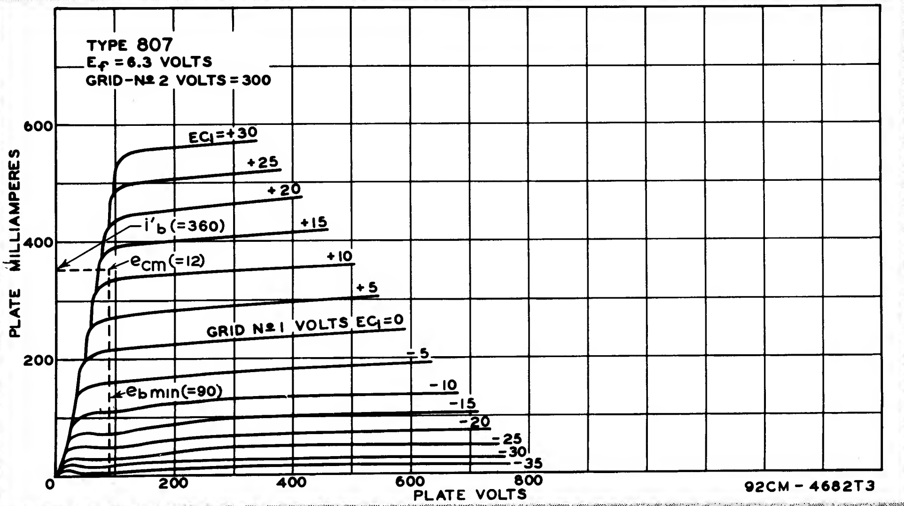

Fig. 1. Average plate characteristics for the type 807 tube (grid-No. 2 voltage = 300).

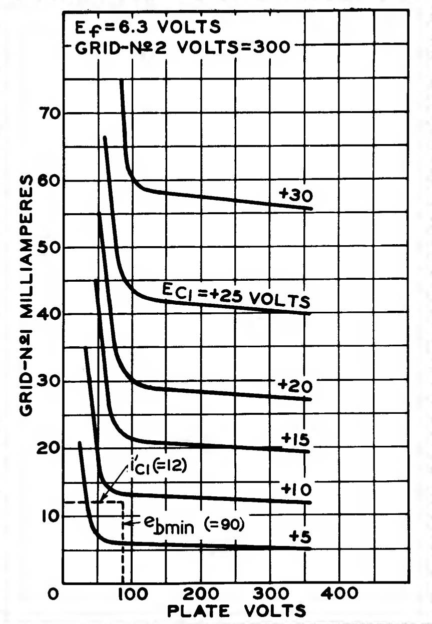

Fig. 2. Average control-grid characteristics for the type 807 tube grid-No. 2 voltage = 300).

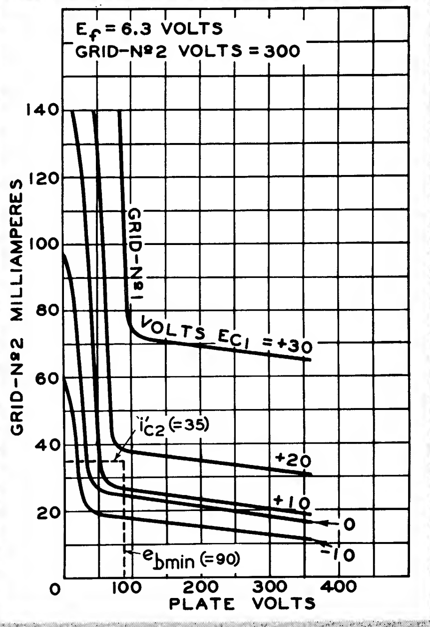

Fig. 3. Average screen-grid characteristics for the type 807 tube grid-No. 2 voltage = 300).

(*Continued from Page 3*)

Table I shows the maximum ratings and typical operating conditions for several popular RCA tubes in linear rf amplifier service for single-sideband, suppressed-carrier transmission.

It should be remembered that the typical operating conditions shown by the manufacturer (or calculated by the preceding methods) are approximate only. Minor adjustments are usually made in actual operation by varying the grid bias or screen voltage slightly. In linear rf amplifier circuits for single-sideband, suppressed-carrier transmission, it is particularly important to check the actual operating conditions when the transmitter is first set up to assure that linear operation within the maximum tube ratings is being obtained.

Table I—Ratings and Operating Conditions for RCA Tubes Used as Linear RF Power Amplifiers

			Maximum Ratings - Absolute Values							Typical Operation								
Tube Type	Class of Operation	Service	Plate Voltage (E_b)	Screen Voltage (E_{c2})	Max-Signal Plate Current (I_{bms})-ma	Max-Signal Plate Input (PI)-watts	Max-Signal Screen Input (SI)-watts	Plate Dissipation (PD)-watts	Grid Resistance -ohms	Plate Voltage (E_b)	Screen Voltage (E_{c2})	Grid Voltage (E_{c1})	Peak Grid Voltage (E'_g)	Zero-Signal Plate Current (I_{bo})-ma	Max-Signal Plate Current (I_{bms})-ma	Max-Signal Screen Current (I_{c2})-ma	Drive Power (DP) -watts	Max-Signal Power Output (PO)-watts
2E26	AB1	CCS	400	200	75	30	2.5	10	30 K	400	200	-25	25	9	45	10		12
		ICAS	500	200	75	37.5	2.5	12.5	30 K	500	200	-25	25	9	45	10		15
	AB2	CCS	400	200	75	30	2.5	10		400	125	-15	30	10	75	16	0.2	20
		ICAS	500	200	75	37.5	2.5	12.5		500	125	-15	30	11	75	16	0.2	25
4-65A	AB1	CCS	3000	600	150		10	65	250 K	1000	500	-85	85	15	85	12		40
										1500	500	-85	85	15	90	7		70
										1750	500	-90	90	10	85	9		85
	AB2	CCS	3000	600	150		10	65		1000	250	-30	105	30	150	22	2.5	85
										1500	250	-35	100	30	125	15	1.5	125
										1800	250	-35	90	25	110	13	1.0	135
4-125A	AB1	CCS	3000	600	225		20	125	250 K	1500	600	-90	90	30	110	9		80
										2000	600	-94	94	25	120	3		115
										2500	600	-96	96	25	115	4		165
	AB2	CCS	3000	400	225		20	125		1500	350	-41	141	44	200	17	5.0	175
										2000	350	-45	105	36	150	3	3.0	175
										2500	350	-43	139	47	130	3	2.5	200
4-250A	AB1	CCS	4000	600	350		35	250		2000	500	-88	88	55	200	11		230
										2500	500	-90	90	60	215	7		310
										3000	500	-93	93	60	205	5		370
	AB2	CCS	4000	600	350		35	250		2000	300	-48	100	60	255	13	5.5	325
										2500	300	-51	100	60	250	12	5.0	420
										3000	300	-53	100	62	236	16	4.5	520
807 1625	AB1									500	300	-32	32	22	70	8		23
		CCS	600	300	120	60	3.5	25	100 K	600	300	-34	34	18	70	8		28
		ICAS	750	300	120	90	3.5	30	100 K	750	300	-35	35	15	70	8		35
	AB2	CCS	600	300	120	60	3.5	25		500	300	-30	43	30	120	10	0.2	38
										600	300	-32	40	24	100	9	0.1	40
		ICAS	750	300	120	90	3.5	30		750	300	-35	48	15	120	10	0.2	60
811A	B	CCS	1250		175	165		45		750		0	100	16	175		10	90
										1250		0	78	25	130		4	120
		ICAS	1500		175	235		65		1000		0	93	22	175		7.5	125
										1250		0	88	27	175		6	155
813	AB1	CCS	2250	1100	180	360	22	100		2000	750	-90	80	25	130	20		165
										2250	750	-95	85	25	125	26		190
		ICAS	2500	1100	225	450	22	125		2500	750	-95	90	25	145	27		245
829B Natural Cooling	AB1	CCS	750	225	250	100	7	30	100 K	500	200	-20	40	20	100	20		35
										600	200	-18	36	40	100	18		44
		ICAS	750	225	250	120	7	40	100 K	750	200	-21	42	20	100	20		55
	AB2	CCS	750	225	250	100	7	30		500	200	-18	50	30	180	26	0.6	60
										600	200	-20	50	26	155	22	0.4	65
		ICAS	750	225	250	120	7	40		750	200	-19	50	32	160	25	0.5	85
832A	AB1	CCS	750	250	90	36	5	15	100 K	500	180	-30	60	14	70	7		22
										600	150	-30	60	12	60	7		23
		ICAS	750	250	115	50	5	20	100 K	750	150	-32	64	12	60	7		30
833A	B	ICAS	3300		500	1300		350		3300		-80	190	60	300		20	710
6146 6159	AB1	CCS	600	250	125	60	3	20	100 K	400	190	-40	40	32	114	13		27
										500	185	-40	40	29	108	13		35
										600	180	-45	45	13	100	12		40
		ICAS	750	250	135	85	3	25	100 K	600	200	-50	50	14	115	14		47
										750	195	-50	50	12	110	13		60
	AB2	CCS	600	250	125	60	3	20		400	175	-41	48	17	116	9	0.2	31
										500	175	-44	51	14	121	9	0.3	41
										600	165	-44	49	11	104	9	0.2	45
		ICAS	750	250	135	85	3	25		600	190	-48	55	14	135	10	0.3	55
										750	165	-46	54	11	120	10	0.4	65
6524	AB2	CCS	500	300	150	70	3	20	30 K	400	200	-23	72	25	145	10	0.1	39
										500	200	-26	70	20	116	10	0.1	40
		ICAS	600	300	150	85	3	20	30 K	500	200	-25	76	25	145	10	0.1	50
										600	200	-26	76	21	135	13	0.1	57

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Joseph Pastor, Jr., W2KCN
Editor

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